NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

STAKEHOLDER VALUES AND PERSPECTIVES WHEN IMPLEMENTING LED LIGHTS ON NAVY SHIPS

By: Matthew S. Brooks, and
Amelia L. Tribble

June 2014

Advisors: Nicholas Dew,
Kathryn Aten

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2014	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE STAKEHOLDER VALUES AND PERSPECTIVES WHEN IMPLEMENTING LED LIGHTS ON NAVY SHIPS			**5. FUNDING NUMBERS**
6. AUTHOR(S) Matthew S Brooks and Amelia L Tribble			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**
13. ABSTRACT (maximum 200 words) This thesis is a study of the technology adoption chain on implementing LED lights on Navy ships and to determine if there is any disparity between stakeholders' Cost Benefit Analysis (CBA) perspectives. It also analyzes the soft sell items that were not considered in the first CBA conducted for the Navy. The full-time equivalent sailor was determined to provide another perspective of how many sailors it actually takes to change a light bulb given a set of variables through the course of a year. The number of full-time equivalent sailors provides an opportunity cost of how many sailors a year each ship will employ only changing one type of light bulb in a given year.			
14. SUBJECT TERMS LED Lighting; Solid State Lighting; Business Case Analysis, Full-Time Equivalent, Cost Benefit Analysis			**15. NUMBER OF PAGES** 139
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

STAKEHOLDER VALUES AND PERSPECTIVES WHEN IMPLEMENTING LED LIGHTS ON NAVY SHIPS

Matthew Seth Brooks, Lieutenant, United States Navy
Amelia Lynn Tribble, Lieutenant, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2014

Authors: Matthew S Brooks

Amelia L Tribble

Approved by: Nicholas Dew, Lead Advisor

Kathryn Aten, Support Advisor

William R. Gates, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

STAKEHOLDER VALUES AND PERSPECTIVES WHEN IMPLEMENTING LED LIGHTS ON NAVY SHIPS

ABSTRACT

This thesis is a study of the technology adoption chain on implementing LED lights on Navy ships to determine if there is any disparity between stakeholders' cost-benefit analysis (CBA) perspectives. It also analyzes the soft sell items that were not considered in the first CBA conducted for the Navy. The full-time equivalent sailor was determined to provide another perspective of how many sailors it actually takes to change a light bulb given a set of variables through the course of a year. The number of full-time equivalent sailors provides an opportunity cost of how many sailors a year each ship will employ only changing one type of light bulb in a given year.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	acquisition category
APALED	All-Platform light-emitting diode
ASN	Assistant Secretary of the Navy
BBL	Barrel (unit)
CBA	cost-benefit analysis
CFL	compact fluorescent lamp
CNO	Chief of Naval Operations
CO	commanding officer
COC	chain of command
COTS	Commercial-off-the-shelf
CMC	Command master chief
DAASC	Defense Automatic Addressing System Center
DAASCINQ	Defense Automatic Addressing System Center Inquiry
DARPA	Defense Advanced Research Projects Agency
DIVO	division officer
DH	department head
DLA	Defense Logistics Agency
DOD	Department of Defense
DOE	Department of Energy
DON	Department of the Navy
EFOI	Energy Focus Inc.

FBCF	fully burdened cost of fuel
FTE	Full-time equivalent
FY	fiscal year
HAZMAT	hazardous materials
HEDLight	High Energy Distributed Lighting
LED	light-emitting diode
LCPO	leading chief petty officer
LPO	leading petty officer
MIL-DTL	military detail specification
MILSPEC	military specifications
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
NAVSSES	Naval Sea Systems Command - Systems Engineering, Specifications and Standards
NAVSUP	Naval Supply Systems Command
NIIN	Navy integrated information network
NMCI	Navy/Marine Corps intranet
NPV	net present value
NPVI	net present value index
NSN	national stock number
NSRP	National Shipbuilding Research Program
NSWCCD	Naval Surface Warfare Center Carderock Division
NSWCCD-SPEC	Naval Surface Warfare Center Carderock Division - Specifications

NSWCCD-SSES	Naval Surface Warfare Center Carderock Division - Ship Systems Engineering Station
ONR	Office of Naval Research
OPNAV	Office of the CNO
PEO	Program Executive Office
PQS	performance qualification system
PV	present value
R & D	research and development
RDA	research, development and acquisitions
RFI	request for information
RFP	request for proposal
RFQ	request for quote
ROI	return on investment
SCC	Squamous Cell Carcinoma
SEA 21	Division of NAVSEA
SECNAV	Secretary of the Navy

Ship Classes:

CG	guided missile cruiser
CVN	multi-purpose aircraft carrier (nuclear-propulsion)
DDG	guided missile destroyer
FFG	guided missile frigate
LCC	amphibious command ship
LCS	littoral combat ship

LHA	amphibious assault ship (general-purpose)
LPD	amphibious transport dock
LSD	dock landing ship
MCM	mine countermeasures ship
PC	patrol coastal
SSN	submarine (nuclear-powered)
SSBN	ballistic missile submarine (nuclear-powered)
SSDG	Ships Service Diesel Generator
SSL	solid state light
SSTG	Ships Service Turbine Generator
TCO	total cost of ownership
USB	universal serial bus
USCG	United States Coast Guard
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics
USNS	United States Naval Ship
USS	United States Ship
WACC	weighted average cost of capital
WCS	work center supervisor
XO	executive officer

ACKNOWLEDGMENTS

We wish to express our sincere appreciation to Professor Nicholas Dew and Professor Kathryn Aten. Your valuable insight and guidance made the completion of this project possible. The pun "how many sailors does it take to change a light bulb" now has a new meaning, so thank you.

We would also like to thank Mr. Mike Seale from Techshot Lighting, Mr. Keith Kazenski and Mr. Eric Hillard from Energy Focus Inc., and Dr. Charles Bruzzone from 3M. You all provided excellent information from the innovator and supply perspective. The insight, expertise and values provided insight into the private sector of innovation.

From the military perspective, we would like to thank Mr. Ben Hatch, NAVSSES, Mrs. Ashley Hanna OPNAV N45E, Mr. Mike Essig, NAVSEA 05T, Mr. Timothy Schuler, NSWCCD (PEO Ships & NAVSEA 21), Mr. Glen Sturtevant, Director S&T and Mrs. Lisa Wallington NAVSEA 05C. Everyone has expressed a large appreciation for this research and allowed this project for move forward. We have a greater understanding and appreciation for the amount of effort that is required to implement new technology on Navy ships and the magnitude of expertise that is necessary even for a simple idea such as light bulbs.

Finally, I would like to thank Kim, Emmily and Reese. Kim, with your complete understanding of the work I have done in the past, will do in the future and your patience with my studies spending a few nights away from the dinner table to complete my assignments. Emmily and Reese, I am very proud of your accomplishments as I have the opportunity to watch you grow. Never stop learning or asking any questions.

—Matt Brooks

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. OVERVIEW

Implementing change in any large, structured organization, especially the Navy, may be difficult. Upgrading lighting fixtures on naval vessels is obviously a more complex undertaking than a similar change at a residence, which might come after a quick discussion with the spouse and a trip to the local hardware store. Changes in the Navy may require the assistance of research, development, and analysis, and multiple decisions, depending on the complexity of the change or implementation.

Organizations, such as the Navy, must continue to implement and accept change. Change is brought about with ideas, concepts, research, analysis and decisions. Ideas begin with a decision and analysis of whether to research the concept further. The analysis brings decisions and possibly predisposed perceptions as well. The idea may fail in the beginning analysis or grow into a complete change. Beginning the process of change requires an initial decision allowing change to happen.

The Department of the Navy is embracing and mandating the requirements to become more energy conservative. OPNAV N45, Navy Energy Coordination Office, has taken an interest into making ships more energy efficient. This is just one entity within the Navy's organization that is interested in changing lighting fixtures and bulbs. Since OPNAV N45 shows interest (not just in name alone) in changing to LED lights on Navy ships, they will be considered a stakeholder.

In today's advanced Navy, new technology is everywhere. Those within the organization may not be able to fundamentally comprehend all the inherent moving parts that are required to take an innovation and transform it into an organic piece on the ship. Understanding how to upgrade Navy ships lighting fixtures and bulbs with solid state lights (SSL) or light-emitting diode (LED) lights can provide insight into the process of change. Understanding the dynamics of implementing even a simple, sometimes trivial utility like a light fixture can perhaps create an understanding behind the tribulations (if any) that is necessary for such advancements.

The Navy is looking to save money in any facet possible on ships. Ships are being forced to stay in port more often to burn less fuel and at shore facilities; everyone is directed to turn lights off at the end of the day. With LED lights advancements in recent years, changing older light fixtures to more efficient LED lights seems almost intuitive. The simplicity of changing a light bulb is what brings this fact-finding case study to light. Is changing a light bulb on a Navy ship really that intuitive as a layman may think?

B. A CASE STUDY ANALYSIS

This fact-finding research project explores the technology adoption-chain perspectives of implementing LED lights on Navy ships and submarines. Along the adoption-chain, values and perspectives may vary from shareholder to shareholder. The end user on a ship values implementing new technology may be different from the vendor's values and perspectives. If any of these participants along the adoption chain fail to see a positive value for implementing LED lights, the program will fail and so will the new technology.

C. RESEARCH QUESTIONS

The initial question arose, why has the transition to LED lights on naval vessels taken so long to implement? This is a great question, however, rhetorical and opinionated. In dissecting the rhetorical inquiry brings the question, to what extent, if any, do stakeholders have different perspectives about the value of implementing LED lights on Navy ships? The question of perspectives and values can answer the rhetorical question. The perspectives will illustrate what length of analysis and decision-making goes into the process of implementing LED lights on Navy ships.

A secondary question, but important to the rhetorical question is, who is involved in the process to implement LED lights and how are conclusions drawn? Within these two questions we can dissect the variables used and interpret how the participants value the implementation of LED lights. Different from divisions or stakeholders through the adoption chain may modify presentations to highlight their values?

D. SCOPE

The study will look at the adoption chain of implementing LED lights on Navy ships and the perceptions of the different players. Archived documents provided by participants will be separated into an analysis or decision-maker portfolio. The documents should illustrate perceptions of each participant on what is valued to implement LED lights on Navy ships.

Each portfolio of analysis' and decision-makers will be compared to determine if the participants have similar perceptions when coming to their conclusions. Financial calculations will be compared to show if perspectives vary within any financial analysis and cost benefit analysis calculations.

E. METHODOLOGY

The research focuses primarily on contacting participants and requesting archived data and documents relating to the implementation of LED lights on Navy ships. Specific documents used for marketing presentations to decision-makers were requested. Comparisons will be made by utilizing tables, graphs and spreadsheets to illustrate stakeholder's perceptions and their values between commercial-off-the-shelf (COTS), return on investment (ROI) and break-even points.

Request for information (RFI) will begin to tell the story of what the Navy is looking for from vendors. The RFI sets the standards for vendors to see if LED lights can be produced to a set of specifications. Request for proposal (RFP) will be issued from the Navy when ready to set contract awards and timelines. The Navy will then award a contract by whatever criteria best matches what the Navy's contracting officer wants (i.e., lowest price with best standards).

A net present value (NPV) or break-even analysis shows if indeed the implementation of LED lights is cost beneficial to the Navy or how long it will take to see a ROI. Databases and spreadsheets that show any NPV and the calculations that were derived from them will lead to stakeholder's values of implementing this technology. If each department does in fact calculate NPV and ROI, are they using the same numbers?

Is each division using a weighted average cost of capital (WACC) and if so, is each value being calculated with the same weight as the other divisions?

II. LITERATURE REVIEW

A. CONCEPTUAL PERCEPTION

Previous research determined the cost-benefit analysis (CBA) of implementing LED lights and SSL fixtures on Navy ships and submarines (Freymiller, 2009). The CBA lends a conclusion to the implementation of LED lights and provided a qualitative analysis of data provided from primary stakeholders and inquirers, such as ONR.

Other research looked at the life-cycle cost of implementing LED lights compared to the existing CFLs. This sheds light on another perspective of the potential time at which the Navy will see the saving (Cizek, 2009).

These two theses provided several insights of different vendors. Cizek's study also provided groundwork for the Coast Guard in determining their value and reasons for implementing LED lights on the Coast Guard ships (Kingsley, Fike, Reubelt, & Amerson, 2012). Therefore, the Coast Guard, at large, can be considered a stakeholder as an end user as well.

B. DEFINING PERSPECTIVES

The framework of perspective in the book *Essence of Decision: Explaining the Cuban Missile Crisis* will serve as the basis on differing perspectives (Allison & Zelikow, 1999). The framework or linkage of implementing LED lights on Navy ships is discussed via Model II: Organizational Behavior Model and Model III: Governmental Politics Model. This framework provides departmental perspectives within an organization that may lead an entire country to the brink of a nuclear war; or in this case, the decision that persuades the Navy to adopt new technology such as LED lights.

Model II encompasses the entire government and has five points: 1) why create a systematic approach? 2) create divisional tasking 3) routines and programs exist 4) organizational culture and 5) organizations are not a comparison to individuals (Allison & Zelikow, 1999). The rest of this section draws on Allison and Zelikow's (1999) five points as they pertain to this particular case.

There are many reasons to create a systematic approach. A complex organization, like the Navy, must be able to decrease the learning curve and create an efficient system with standard procedures. An individual's mentality is removed from the equation as the person will act on behalf of the organization. The individual's commitments are towards the division, department or organization, the U.S. Navy in this case. The organization must outline its specific department's missions to provide the best outcome in its favor. If the department's specific mission is not directed then the values of the organization will not be in line and a breakdown in communication occurs.

The Navy's hierarchal organizational structure, which will be addressed later in this chapter, illustrates levels upon levels and departments next to departments. The Navy provides guidance to these departments and subdivisions on what they must value. For instance Naval Sea Systems Command (NAVSEA) is directed to be the engineers of the fleet.

The Navy has created organizations within it and is fragmented into specific task-oriented departments. These departments harness individual's expertise. NAVSEA is a task-oriented command of the Navy. NAVSEA Code 05S is a specific division that determines the standards that all vendors must follow when manufacturing LED lights for Navy shipboard application. ONR's specialty is not determining standards, but coupling innovation with the fleet. Together, these two entities alone can provide technological advances to the fleet, with a viable product.

Specific routines throughout an organization will also dictate the value that is placed on particular innovations. The Navy is a warfighting organization and sets up routines to train in war scenarios and procedures to defend the nation. Finding the time to change light fixtures may be undervalued in a warfighting organization. Where would changing light bulbs come into play? Breaking the routine of the 30-year-old light bulb with new technology must be decided at some point in time, by whom, when and how?

The culture created by the Navy organization and within its subdivisions is important. These cultures produce and value different procedures, policies and standards to make decisions. To start at determining what the culture is like, we can look to the mission

statements from the different commands. The mission statements and policy standards set a broad, overarching purview of what the concerns should be within the command.

The departmentalized structure of the Navy, each command must interact with other commands to some extent in order to complete the defined mission of the Navy. We will look at a basic illustration of how the Navy has developed its routine to implement LED light bulbs on ships. From the illustration or flow chart and documentation that is provided, we can look at a broad view of the interaction that takes place within the different departments. The complex interaction different organizations create can determine if new technology, like SSL fixtures, will be implemented (Allison & Zelikow, 1999).

C. ADOPTION CHAIN

To consider the potential of implementing LED lights on Navy ships, we look the adoption chain depicted in Figure 1 (Adner, 2012). The adoption chain of technology provides an influential assessment from each stakeholder. Within the adoption chain, each stakeholder provides his or her assessment and creates a positive or negative value (Adner, 2012). The overall assessment from the adoption chain summarizes the values from the stakeholders. However, regardless of whether the overall net value for implementing this change is positive, if one stakeholder in the adoption chain has a negative assessment, the adoption will be rated as a negative value. This new technology therefore will fail to ever be implemented.

The adoption chain is based on four distinct positions; innovator, distributor, retailer and end customer (Adner, 2012). Each stakeholder will provide a weighted value based on their individual, divisional or organizations' perspective. An innovator and distributor may value adopting LED lights as positive 3, the end customer value is a negative 1 and the retailer is a positive 1. Although the overall net value is positive 6 (+3+1-1=3), there is still one stakeholder that has a negative assessment when rating the implementation of this new technology. Therefore, the total adoption chain assessment is valued as a failure. LED lights should not be implemented on Navy ships using this model, with these assessments. As illustrated in Figure 1, the net value is +6, but the minimum is -1.

Figure 1. Adoption chain (after Adner, 2012)

A positive value is necessary from each stakeholder in order for the new technology to be efficacious. The distributor and retailer may provide excellent prices and even incentives for the product, but if the end user does not value the product in a positive fashion, then the product will ultimately fail. The end user will never purchase the product. On the other hand, if the end user values the product positively, but the distributor values the product negatively, the end user will never see the product, as the innovation will never be purchased for distribution.

We figure there is an exception to this perceived value adoption chain. Externalities, such as new policy or laws to decrease fossil fuels, may tend to impose a higher value to a product. Thus, the forcing function would not take the adoption chains net value into consideration. This thesis would be different if the CNO or SECNAV mandated LED lights to be installed on all naval vessels. A new mandate would veto all valued assessments in the adoption chain as the precedence to implement LED lights would be policy not valued perception.

It is possible for the customer or end users to value a particular innovation like LED lights differently. LED lights are supposed to last almost 20 years. To a maintenance person on a ship, a 20-year light bulb will mean that sailor will never change any light bulbs during his or her tenure on that vessel. The sailors performing the maintenance may rate this product or innovation with a value of +50. The innovator needs should certainly feel the product as a positive value; otherwise they probably will not invent the LED lights in the first place.

The idea is to change the lighting onboard Navy vessels. It will save the maintenance personnel time and energy that is can be utilized preparing or maintaining for the ships primary mission rather than changing light bulbs. What is missing in

transforming the adoption chain of LED technology? Any piece of equipment that is going to be changed on a Navy ship must be approved through a chain of command and meet all the required specifications defined by NAVSEA. Commercial-off-the-shelf (COTS) LED lights may not meet the rigorous required testing.

THIS PAGE INTENTIONALLY LEFT BLANK

III. RESEARCH APPROACH

A. IDENTIFYING ADOPTION CHAIN

All the participants must be identified to fully understand how to implement LED technology adoption chain works. In small organizations, there may be a small research and development team with a financial analyst used to formulate spreadsheets and any ROI or NPV calculations along with standards set by an engineer. They may have a project manager or a team leader to present their findings to the facilities manager and the facilities manager may make the ultimate decision to implement COTS LED lights throughout their building. It is even possible that all these jobs are performed by the same person who also makes the decision.

We must look at all the entities that will analyze or make a decision to implement LED lights on a Navy ship. Once those decision-makers and analysts are identified, then the data they used will come into question. If the analysts are receiving data from vendors, then the vendors are now partaking in the decision process. The entire supply chain may also play into how the final decision will be. If there is no supply of LED lights, then a decision should be very easy to make; do not implement something that does not exist.

We begin by looking at the different perspectives of stakeholders and what needs to happen to implement LED lights onto Navy ships. Determining who the participants are for the implementation of LED lights is important. Each contributor in the process provides a different perspective and value when installing this new technology.

Expanding on Adner's adoption chain in Figure 1, this model must be identifying to the Navy's way of implementing technology. Given, the way the Navy implements a total weapon system from lights is different, In Figure 2, the adoption chain is expanded to meet a broader range of stakeholders. We want to discover if there is a variety of values between the different stakeholders or are they the same. Breaking down the participants by type of contributions further groups their values and perceptions. Determining the type of contribution these participants create, direct or indirect, can

illustrate the value of the placed in the adoption chain. This separation will also show the type of perceptions made, the various values and the importance of each value per stakeholder.

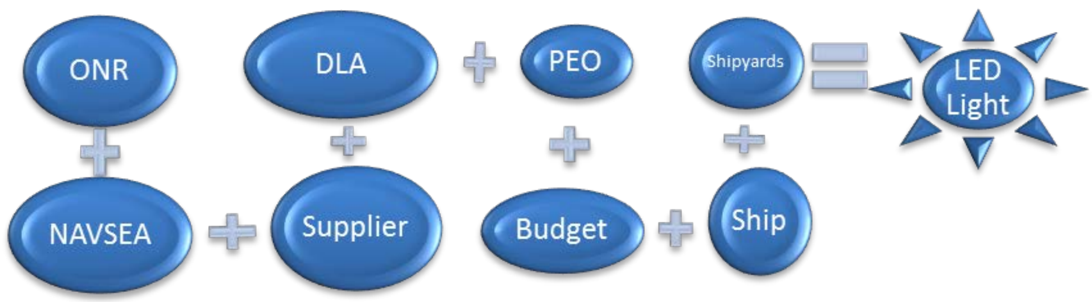

Figure 2. Big picture LED lights adoption chain without subdivisions (after Adner, 2012)

B. DIRECT CONTRIBUTORS

Each participant, department, corporation or lobbyist may value implementing LED technology on ships differently. A distinction must be made between the maintenance man and the finance department, as they intuitively place a different value on the change of technology.

Stakeholders will be placed in the categories along the technology adoption chain. This will help determine if the implementation will be useful for one ship class verses another; or one manufacturer verses another manufacturer. Implementing LED technology requires the same type of maintenance from one ship to another. The particular ship a maintenance man serves on can affect its life expectancy or deployment cycle. A ship may be decommissioning, or going through a modification. While the maintenance man values implementation because he anticipates less work, the ship's project managers see it differently, gauging cost investment against the life of the ship. .

The players become apparent after the initial request to place LED lights on submarines is placed. A submarine sonar technician objected to the humming of the 60 hertz from the CFL fixtures and placed a request with ONR, TechSolutions (Ottman D. E., 2011). Now we have a basis for the problem and three players named.

ONR, TechSolutions takes requests and ideas from sailors and determines the feasibility of the request. TechSolutions is a division within a department of ONR (see Figure 3). The Office of Innovation is yet another. TechSolutions is a small part in the adoption chain for implementing LED lights on ships. ONR-funded grants for research to third parties that have expertise in the field of lighting and solid state devices.

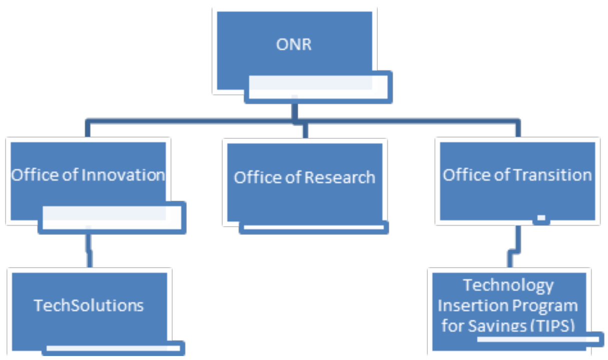

Figure 3. ONR divisional organization (after ONR.navy.mil)

Naval Sea System Command (NAVSEA) is an essential element in the Navy's adoption chain. NAVSEA sets the standards for all systems and approves any changes incorporated on Navy ships and submarines. They are essentially the engineers for the fleet. NAVSEA has its own organizational structure that is very unique. We will focus those divisions (Navy codes) that pertain directly to implementing this specific change request to Navy ships. Figure 4 illustrates the different codes that are involved in implementing LED lights on Navy ships.

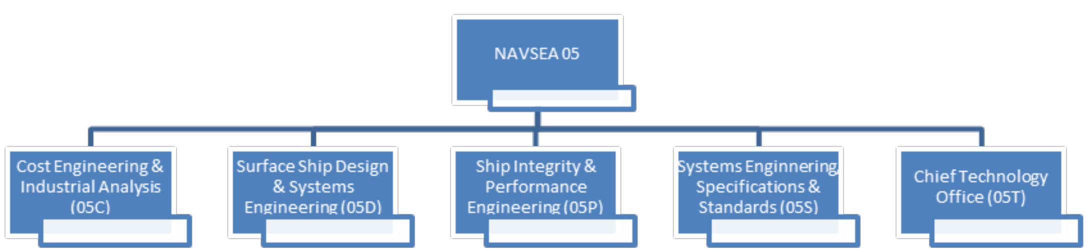

Figure 4. NAVSEA divisional organization that is pertinent to implement LED lights on Navy ships - Code 05 (after NAVSEA, 2011)

There are several manufacturers of LED light bulbs. Like many other devices on Navy ships, the rigorous specifications can drive those manufacturers to a halt. A request for inquiry (RFI) was sent to vendors to identify interest and ability to replicate the product. Figure 5 shows 10 different vendors that have shown interest. How do vendors value the product? If none of the vendors reproduce the standards, then the technology adoption chain will fail, and LED lights will not be implemented until a vendor finds value to meet the standards.

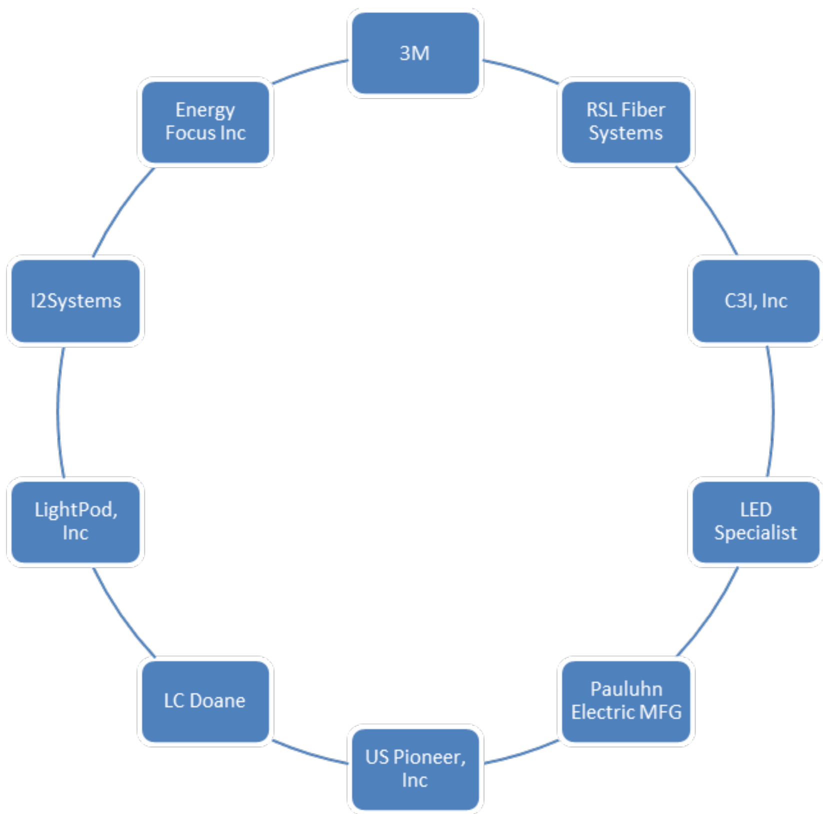

Figure 5. Vendors that received LED light specifications from NAVSEA's distribution list (after Kingsley, Fike, Reubelt, & Amerson, 2012)

The representative to stock LED lighting fixtures has a certain perspective as well. With adding one lighting fixture to a supply system, you either take the other lighting fixture away, or the system must now procure two lighting fixtures, adding cost and complexity to the supply system. Storage, supply and demand becomes a factor

when NAVSUP or DLA values the implementation of LED lights on Navy ships. This is something we will address in the Chapters IV and V.

Almost all participants in the adoption chain have been identified. Although NAVSEA gives the approval for the specifications and the standards that will be met, the ships representatives, also have a say in implementing any change on their ships. A simple change such as switching a lighting system is not so simple. Therefore, Program Executive Offices (PEO) Ships will have their own outlook on whether this cost is really a benefit.

A partial breakdown of the ASN (RDA) chain of command (COC), Figure 6, illustrates only participants within the COC that can affect the implementation of LED lights on Navy ships. All departments are considered to have analysis and decision making powers within their own divisions. Discovering which entity has veto power in the equation is important as well. In the fact finding expedition, determining the different perspectives in each division by how they value the implementation of this growing technology is important.

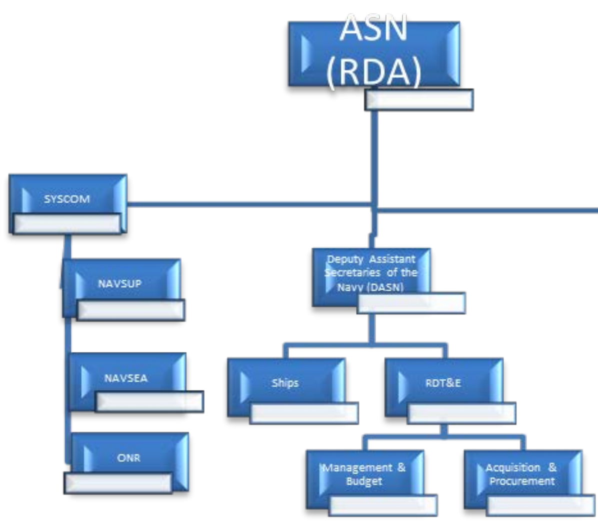

Figure 6. COC for the Office of the Assistant Secretary of the Navy (Research, Development and Acquisition) the is utilized when implementing LED lights on Navy ships (after DASN M&B, 2012)

These are the major participants within the adoption chain for implementing LED lights on Navy ships. For all the participants in Figure 6, priorities must be set based on the divisions or specific organization's needs and mission. Every participant should be concerned with standards and ship's safety. If the standards are met and the ship is safe, is the value placed on modifying all the lighting fixtures throughout the Navy the same value as say Defense Logistics Agency (DLA)? The vendors may be concerned both by price and by quality as well. But are all the participants placing the same weighted value to the project of implementing LED lights on Navy ships?

C. INDIRECT CONTRIBUTORS

Many outside entities can persuade, mandate or direct the implementation of LED lights. President Barack Obama directed federal agencies to decrease the footprint of greenhouse emissions by directly and indirectly decreasing the use of fuels, like implementing new technologies (Executive Order No. 13514, 2009). This order may have influences certain decisions or added weight toward the implementation when maybe the costs outweighed the benefits. The externality of this order could be the implementation of costly products.

SECNAV provided further direct guidance to the Navy. SECNAV delineates positional authority for the Navy's energy conservation efforts. However, this did not mandate the improvement of lighting fixtures on Navy ships. Certain jobs were refocused to energy efficiency and may now utilize new technology that was available but undervalued prior to this point.

Within the DON, there is a dedicated Energy, Environment and Climate Change division, OPNAV N45. OPNAV N45 can be considered to be lobbyist for implementing positive change to the environment in the Navy. Task Force Energy reports to the Deputy Chief of Navy Operations for Fleet Readiness and Logistics (CNO N4). CNO N4 leads working groups as well as the Energy Transition Office and an Executive Steering Committee (Lobbyist). OPNAV N45 has a particular interest in the implementation of new technology that can improve the Navy's energy usage fleet wide.

Determining the main players in the adoption chain is imperative. The roles each of these participants play leads to the overall assessment value through the adoption chain. Using the adoption chain model, each stakeholder has veto power not to implement the LED technology. An overarching determination is when a mandate or policy overrides a stakeholder's values. If there is a policy change mandating the implementation of LED technology the adoption chain valued assessments will be insignificant. The only stakeholder value that matters is the policy maker because all others must follow suit. We will see how the values of material specifications are valued when mandated in chapters IV and V.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. PERSPECTIVES VALUES AND FINDING

A. INITIAL PERCEPTION

Our perception of implementing LED lights on Navy ships and submarines may appear skewed due to the limited access of old or proprietary information. LED lights have been in conception for over a decade decades and a lot of the initial data was unavailable. Another reason for the skewed perception is that intangible data analysis of the initial idea has not been accessed.

The Navy issues press releases and strategy adaptions to appeal to the public on being environmentally friendly. The Navy cares about its capability and efficiency. Aligning the "Green Fleet" with the current operations can increase this capability. If a green system brings more capability, then it is likely to be adopted, if it can pass the NPV and payback barrier. If it does not bring more capability, then initiative will not be valued and will not be adopted by the Navy. Creating additional ways to fuel the fleet addresses the critical vulnerability of relying on oil for fuel, an essential and limited resource. Without oil, the DOD would not have the capability to sustain the operations and mobility that we currently deploy.

The technology adoption chain for the Navy appears more complex than Adner's model. Adner's model afforded a generic foundation with very distinct areas to address implementing new technology. The stakeholders within the Navy's technology adoption chain become intertwined when classifying solely innovators, distributors, suppliers and customers.

In 2009, two theses were conducted at the Naval Postgraduate School. One thesis consisted of a business case analysis and the other a comparative analysis of LED shipboard lighting (Cizek, 2009; Freymiller, 2009). The business case analysis consisted of a NPV and break-even analysis of implementing LED lights on Navy ships. These studies have been referenced by various stakeholders within the adoption chain. These references appear to provide a group think mentality. Positively the research provides communal a values and conversely can lack depth if all avenues are not pursued in the

beginning. The second, third and follow-on effects may not be examined by all stakeholders if only the avenues pursued in these studies are insufficient.

The Navy is not a business, so to speak, as capability, strength and force may not always be proven using calculations. The clear cut line regarding who benefits from implementing LED lights can be misjudged. Limiting fuel consumption may not always produce a savings benefit where power consumption is inconsequential such as nuclear powered ships and submarines. As managers and decision makers, it is important to create a full picture of all benefits when adopting new technology (J. Goudreau, personal communication, May 5, 2014).

The original perceived reason for changing bulbs is to save energy, reduce fuel cost and fuel dependency. This perception has evolved placing a higher value toward the maintenance man while still valuing the energy savings. In 2009 when the original CBAs were conducted fuel costs were $2.77 per gallon (Cizek, 2009). DLA currently charges $3.61 per gallon or $151.62 per barrel (DLA Energy Standard Prices, 2014). This price increase from FY09 to FY14 is lower than the inflation rate of 1.88% (Joint Inflation Calculator, 2014).

Every stakeholder is concerned with the maintenance person and the cost of direct labor. The cost of a maintenance man, on average, has decreased since 2009. Table 1 compares FY10 and FY15 averages for E-1 thru E-4. The current average hourly rate for an E-1 thru E-4 is $29.34, which is lower than the inflation rate of 1.075% (Joint Inflation Calculator, 2014). The decrease in average pay is very small and negligible in comparison, but it illustrates how the pay scale trended over several years.

Military Pay Grade	Annual DoD Composite Rate FY 2015	Annual DoD Composite Rate FY 2010	Actual Inflation Factor 1.075 (FY10 in FY15 dollar)	% Difference between FY15/FY10
E-1	43,545	44,472		
E-2	48,823	48,943		
E-3	54,895	54,661		
E-4	66,103	64,966		
AVERAGE	53,342	53,261		
Avg Hourly E-1/E-4 Rate	$29.34	$29.29	$31.49	1.001707067

Table 1. Annual DOD Composite Rate FY2015 versus FY2010 (after Cizek, 2009; Deputy Director, Office of the Under Secretary of Defense [Comptroller], 2014)

A supervisor's salary is a cost that was not considered by the stakeholders. Supervisors are not considered inconsequential to product integration in its initial stage. In the private sector all supervisor's salary are lumped into overhead cost when considering to out-source a product, continue manufacturing the product in-house or cancel the product line. A supervisor in the Navy may not necessarily be reassigned when substituting a product, however figuring an estimated time a supervisor will add to the cost of a product may assist in the decision process. Understanding the time maintenance takes per supervisor can assist in evaluating the required personnel when manning a ship optimally.

In upcoming paragraphs the average hourly rate will be an added cost as indirect overhead. Paygrades E-5 thru 0-5 annual salary will be considered to figure the total hourly rate as illustrated in Table 2.

Military Pay Grade	Annual DoD Composite Rate FY 2015	AVG Hourly Rate
E-5	82,120	45.17
E-6	96,939	53.32
E-7	110,765	60.92
E-8	122,917	67.60
E-9	145,276	79.90
0-1	94,738	52.11
0-2	118,890	65.39
0-3	150,534	82.79
0-4	175,523	96.54
0-5	197,347	108.54

Table 2. Annual DOD Composite Rate FY 2015 E-5 thru 0-5 (after Deputy Director, Office of the Under Secretary of Defense [Comptroller], 2014)

B. INNOVATORS

In the Navy's technology adoption chain, reducing energy savings was the fundamental idea when the first contract was awarded in 2002. There was no mandate to implement LED technology at this time. T12 light bulbs were not obsolete at the initial inception of LED lights on Navy ships.

Commercial LED bulbs have been available to the public about two decades. DARPA and ONR are considered the innovators as these commands strive for innovation. A submariner requested to ONR to have LEDs implemented on submarines, because his fluorescent berthing light was noisy and had a short life expectancy (Cizek, 2009). The innovator's value for LED lights is not considered during the standards created by the other stakeholders. The idea to alleviate noise and maintenance requirements on a submarine is considered in the implementation process. A specific standard for noise level does not provide in any quantifiable analysis, so it may not appear through all the stakeholder's values.

1. DARPA

The Defense Advanced Research Projects Agency is where many ideas are born for the Department of Defense. It is the DOD think tank and "one of DARPA's key core

technology areas focuses on power and energy" (Gourley, 2013, p. 176). The development of new technologies and researching how the different services might incorporate them into operations is DARPA's mission and currently the emphasis is on reducing the military's reliance on petroleum.

One of DARPA's focuses is on High Energy Distributed Lighting or HEDLight. This is the next step of LEDs. HEDLight uses LEDs and plastic optical light pipes to achieve two effects: having the fixture in easy packaging and with a longer life expectancy (to the order of 10 times that of a fluorescent), and relocating the fixtures to easily accessible places from hard to reach which require replacement only while in port (Gourley, 2013, p. 176) This "enables significant reductions in platform vulnerability through the use of remote source lighting…with a secondary emphasis on enabling improved visual acuity of the warfighter" (FY03 Cooperative agreements, 2003, p. 48).

The perspective from DARPA is that LEDs are needed on Navy warships. If LEDs can be used and are needed, then the HEDLight is the next step. The HEDLight does have the potential to reduce lighting failures due to high vibration operations, such as on a CVNs flight deck by removing the actual fixture away from the highest vibration, however, further planning is needed in the implementation. Currently, four ships have been retrofitted with the HEDLights, the USS Wasp (LHD 1), *USS Pearl Harbor* (LSD 52), *USS Chafee* (DDG 90) and the *USS Makin Island* (LHD 8) (Gourley, 2013, p. 176). On the amphibious ships (LHDs), the well deck is the primarily where the HEDLights are located, but planning on the location of the remote fixture can cause problems.

2. Office of Naval Research

The Office of Naval Research (ONR) provides the U.S. military research and development initiatives. This department provides the leading edge in innovation for Navy ideas, either utilizing COTS or assisting with the research and development of a new product. In coordination with DARPA, ONR was key in developing the new direct form-fit-function light fixtures that were first placed on the *USS Chafee*, *USS Preble* and *USS Pearl Harbor*.

ONR received the initial interest in LED lighting through their division TechSolutions, which accepts requests and suggestions from individuals in the fleet. The sailors asked for a change, but Navy and DOD leaders were already thinking of this change. “Naval leaders have issued a set of ambitious new goals to boost the Navy and Marine Corps' energy efficiency and solid state lighting supports their plans to make the Navy more green” (Ottman 2012, p. 15).

On the forefront of energy reduction, ONR initiated the process and attempted to tap into resources already in-place into the lighting industry.

> Although the SSL is in its early stages, the LED fixtures are showing great promise. Not only are they a quality of life improvement, but compared with fluorescent light, LED fixtures last longer. They are more efficient, reducing maintenance requirements, energy usage and costs associated with storage, handling and disposal. Long term, SSL usage fleet wide could add up to considerable savings and improved readiness. (Ottman, D. E., 2011)

TechSolutions was not trying to reinvent the light bulb, just merely seeing if better lighting solutions could conform to shipboard standards: “TechSolutions is a rapid-response program that accepts recommendations and suggestions from Navy and Marine Corps personnel on ways to improve mission effectiveness through the application of technology” (Ottman, D. E., 2011, para. 14).

The initial request for berthing lights got phased into emergency lighting and globe lighting fixtures. This is a smaller task and requirement to meet. The bulbs are closer in size and resemble the COTS bulbs originally available. “TechSolutions worked with Energy Focus to produce patented LED fixtures that are direct replacements for fluorescents” (Ottman, D. E., 2011, para. 11). “While Energy Focus fixtures have had a good track record on Navy ships; TechSolutions' products were the first to be fully qualified by the service. Those components met the most stringent electromagnetic interference standards, requiring innovative manufacturing methods” (Ottman, D. E., 2011, para. 13). “Making any electrical appliance tough enough to pass Navy shock and vibration tests is a challenge,” stated Roger Buelow, chief technology officer at EFOI (Ottman, D. E., 2011, para. 13).

3. NAVSEA

In 1794, a single command was formed to orchestrate the construction of a 44-gun frigate (About NAVSEA, 2014). This coordination ensured the Navy was constructing the ship with the community in mind. The Navy established NAVSEA as the one command that has technical authority to create and enforces design standards for Navy ships. This provides the Navy one command that dictates technical standards improving the Navy's efficiency and capabilities. NAVSEA adds value for a specific set of standards. If there is one command whom can veto new technology onto a ship, that is NAVSEA. The veto power that is infused in NAVSEA comes mainly from the technologies qualification process. The NAVSEA organization is broken into various activities. A major player in LED lighting is Naval Surface Warfare Center-Carderock Division (NSWCCD). Within NSWCCD are various divisions such as the Ship Systems Engineering Station (NSWCCD-SSES) in Philadelphia. NSWCCD-SSES approves and certifies a company that can manufacture a product for sale to the Navy and meet all the standards and specifications. This is the only way a vendor can sell a MIL-SPEC product. NSWCCD-SSES also acts as the integration point as the "in-service engineering" technicians (Ship Systems Engineering Station, 2014).

In 2010, NSWCCD issued an RFI that outlined the values and standards set in place (Markey & Hatch, 2010). The material valued for MIL-DTL-16377 provided the lighting minimum, which was already in use. The efficacy request needed to meet brightness, shock test, weight, electromagnetic interference emissions and susceptibility, vibration susceptibility and high impact shock test.

Within the RFI, NSWCCD states, "Replacing the MIL-DTL-16377 fixtures with solid state Light Emitting Diode (LED) fixtures is intended to dramatically reduce maintenance, reduce on board spares, improve reliability, increase light output and improve efficiency. The SSL luminaires shall draw less power than the fixtures being replaced" (Markey & Hatch, 2010, p. 2). Certain restrictions that were brought upon in the RFI are that the new fixtures and lights must not exceed the dimensions and same mounting features of the legacy fixtures. Adaptors or kits to fit the old mounting brackets were not authorized. As innovators, this tends to limit and constrain those further down

the adoption chain, such as suppliers (T. Schuler, personal communication, April 15, 2014).

These specifications have also resonated with each stakeholder. Each stakeholder understands the Navy requires higher standards than commercial users because of the potential dangers inherent in Navy operations. Excessive vibrations on a ship should not be the cause of a light bulb being changed or damaged. The vibration specification ensures operations, i.e. flight, amphibious or live fire missile operations, do not loosen any fasteners, crack or bend the fixtures or bulbs.

Electromagnetic interference is also a major concern that is understood by all the stakeholders. A standard that raises a question is the high impact shock test. The high impact test requires a lighting fixture to be hit nine times and not dent, crack or chip while remaining fully functional (T. Schuler, personal communication, April 15, 2014; Farmer, 2011). This is to simulate combat situations. A common question raised by some stakeholders within the acquisition, distribution and innovators was if a berthing light really requires that type of resiliency? This is where the NAVSEA engineer requiring the high standards and the other stakeholders throughout the technology adoption chain differ. These standards and testing alone raises the price of a single bulb and fixture exponentially.

C. SUPPLIERS / MANUFACTURERS

The variety of suppliers accessible to the commercial LED lighting industry is abundant. The military on the other hand does not have the depth of suppliers available. There is a demand for this product, therefore a supplier is required.

As in any product, suppliers desire to create a profit or receive a return their investment. Naval ship lights are a very small niche in the overall lighting industry. There are currently 289 ships in the Navy’s fleet and each ship has a variety of types of lighting fixtures and bulbs (Department of the Navy, 2014).

The ability for companies to gain entry to meet the Navy standards is extremely costly. The ROI for suppliers must also prove profitable. As of April 29, 2014, there are

only two qualified suppliers for overhead LED lighting fixtures and one for berthing fixtures. (T. Schuler, personal communications, April 15, 2014)

1. EFOI (Energy Focus)

Through personal communications with Mr. Kazenski and Mr. Hillard we have received their perspective regarding EFOI values and history. EFOI has been in the market to put LED lights on Navy ships since 2002. EFOI worked with DARPA during the initial phases of implementing LED lights, gaining certification and contracts to implement LED lights on Navy ships by qualifying under the standards set by NAVSEA 05Z. They received a qualified letter from NAVSEA stating their LED products met all military specifications in 2009. (K. Kazenski and E. Hillard, personal communications, January 31, 2014)

EFOI set out to seize the opportunistic advantage, being the first qualified vendor offered. EFOI grew out of Fiberstars, Inc. that manufactured pool and spa lighting, and, in 2002, received a $10 million contract from DARPA to begin the qualification process. Currently, Energy Focus is the leading supplier of the M1 IntelliTube LED lights that the Navy is using to slowly replace the current fluorescents, both fixtures and bulbs (K. Kazenski and E. Hillard, personal communications, January 31, 2014). With both the $23 million naval contract to retrofit the fleet and the APALED NSRP contract, Energy Focus has solidified its position as the first and one of the only authorized providers for the new LED installations. (Energy Focus Inc. Under Contract to Develop an "All Platform" LED Lighting System for New Navy Ships, 2013).

EFOI appears to be looking to get into the small niche of an industry. The expected market for LED lights is $630 million (Energy Focus 2013 Presentation), estimating that the U.S. Coast Guard (USCG) and Military Sea Command (MSC) will require upgrades to their lighting systems as well. Both the USCG and MSC conducted studies on the value of LEDs and CBAs (Kingsley, Fike, Reubelt, & Amerson, 2012; Bowers, Goering & Leiderman, 2012).

From our perspective, as a supplier, EFOI is looking for that competitive edge and considers the benefits of the end-user. For example, in the legacy berthing light a power

receptacle is available. EFOI took this one step further and placed a USB port in one of their models available to the Navy (Energy Focus Inc. Under Contract to Develop an "All Platform" LED Lighting System for New Navy Ships, 2013). EFOI currently has 6 different types of berthing lights that are available for the Navy to purchase (Energy Focus Inc. Under Contract to Develop an "All Platform" LED Lighting System for New Navy Ships, 2013). .

2. L.C. Doane

L.C. Doane is a lighting company based in Connecticut. This company is the second supplier to receive a qualification approval letter from NAVSEA regarding LED lighting fixtures. L.C. Doane is a large supplier for the Navy's CFL bulbs and fixtures. The company has been supplying fixtures and lights since 1947 (L. C. Doane Company, n.d.). We were unable to contact or receive any information directly from them. We could perceive that L.C. Doane values must remain with their core competency in the lighting industry. Having supplied the Navy for many years and CFL's going obsolete; L.C. Doane is finding a substitute for their own product by moving towards LED lighting. Currently, L.C. Doane has received qualification to supply the Navy with replacing the CFL single, double and three-bulb overhead fixtures (B. Hatch, personal communication, March 25, 2014)

3. Light-Pod Inc.

This is one vendor that is currently working towards a qualification. We were unable to get direct information or presentations regarding their LED lights on Navy ships. Light-Pod is a small LED lighting company that is based out of Philadelphia who specializes in engineering and design of SSL lighting. The lighting fixtures are geared mainly toward military and commercial applications (Light-Pod Military Compliant LED Lighting Fixture, 2008).

4. 3M

We gain 3M perspective and valves through personal communications with Dr. Bruzzone. 3M is another supplier trying to gain entry into the business of supplying LED

light bulbs to the Navy. 3M values are perceived to be driven by how the end-user can benefit from this product. The end-users perceived values were taken into consideration as 3M looked at their product and considered it for Navy ships (C. Bruzzone, personal communication, April 25, 2014).

Through personal communications with the companies and the Navy, a consistency was seen to create the greatest return for their product, by working towards installing LED lights during the construction phase on Navy ships. Benefits were perceived to be greatest for all stakeholders at the construction point (SCRA, 2014; B. Hatch, personal communications, March 25, 2014; T. Schuler, personal communication, April 15, 2014, C. Bruzzone, April 25, 2014). A shipyard could install new LED fixtures in the beginning of the construction phase. This would benefit the shipyard as they would not have to change bulbs during the entire construction phase except maybe once prior to delivery to the Navy (SCRA, 2014). The shipyard can benefit the same as the sailor does, lower maintenance requirements.

The Navy can benefit from getting a longer recoupment period. The Navy is going to pay labor for the shipyard workers putting up lights regardless of the type of fixture. The shipyard will also benefit from a reduction in the shore power consumption, decreasing their overhead cost (SCRA, 2014). 3M suggest the payoff period would then only be 1.9 years for the Navy under this plan, therefore costing the Navy less. This correlates to $100-$300 savings per light fixture (3M TOC of Lights, 2013).

A core value of 3M appears to be the total ownership cost model. 3M also utilizes a model called new product vitality index (NPVI). This provides the company insight into how well a new product is competing and whether the product is still marketable. As 3M does value innovation, NPVI assists in attempting to stay ahead of an aging product (C. Bruzzone, personal communication, April 30, 2014).

5. TECHSHOT LIGHTING

This company is not directly associated with lights on Navy ships, however, Techshot Lighting supplies the Army and Marines a shelter lighting system that can be utilized in tents or make-shift mobile unit. Since they supply another military department

we looked to see if there are any perceived values distinguishable or comparable to shipboard lighting systems.

Through personal communications with Mr. Mike Seale we received Techshot Lightings perceived values on LED lights for the Army and Marines. The type of lighting features a string of bulbs that interconnect with one another can be used overhead in tents or a medical unit's surgical area. The installation is easy, fast and does not require any tools, except a ladder. If one bulb burns out or needs to be replaced, it can be disconnected and reconnected within minutes. There is a master switch for the entire string or each bulb has an isolation switch. The fluorescent bulbs life-expectancy, power savings and limited amount of maintenance are comparable to shipboard LED lights. The expectation is to replace one LED bulb for every five fluorescent bulbs. The fluorescent bulbs are different life-expectancy than the T12's we have been discussing, but will likely follow the diminished quality and efficacy as they become obsolete in the future (M. Seale, personal communications, January 17, 2014).

We analyzed the similarities and differences between the tent light and a shipboard light a few similarities stood out. The perceived payback period could change depending upon who was viewing it. The fully burdened cost of fuel (FBCF) was consistent and the maintenance person was comparable. The figures would appear consistent, however the meaning of the value changed from the stakeholder that was viewing it. The life-expectancy of the bulbs was based on a 24-hour/365 day period. The Army and Navy do use different annual FBCF and maintenance salary averages, but the differences are negligible. The payback period Techshot lighting advertised was 2.5 years for their LED lights (Shelter Lighting System [SLS], 2012).

This payback period was initially better than most ships, so why would there be any doubt of this simple payback period? The major difference between the Navy and Army is in the construction and use of the product, the end-user. What is life-expectancy comparison of a tent to a ship? During ships construction, a light fixture becomes a fixed object and will not be removed. When a tent is constructed, lights go up and will remain there until the unit moves again. The life-expectancy of a tent is where the figures can change or might be valued differently. Light bulbs are considered consumables and to a

soldier who is packing-up the tent for another move, consumables may be considered added weight to pack. These small consumables may be left behind, regardless of the investment cost. The life-expectancy for a ship has become a standard 30 years, but for a tent I do not believe they are expected to last that long, even with long-lasting LED lights. The variable in the valued perception by the actual life-expectancy creates uncertainty for the expected payback period.

D. DISTRIBUTOR

The distribution when implementing new technology on Navy ships can be perceived a few different ways. The Defense Logistics Agency (DLA) and Naval Supply Command (NAVSUP) distribute parts, consumables, food or gas when requisitioned by the fleet. NAVSEA also has the capability and initiative to transition new technology onto the fleet as necessary. Both of these distribution avenues have their own perceived values within the technology adoption chain.

1. DLA

DLA and NAVSUP value the national stock number (NSN) that is given to each product. If a part is not readily available, they can locate an appropriate vendor, procure then distribute the part. The NSN provided for the T12 LED Intellitube replacement is 6240-01-610-2124. The NSN allows DLA the ability to purchase a part from an approved vendor.

As a distributor, DLA sells their products to the end-user, "sailor Jones". DLA appears to mark-up the price during this process. On May 15, 2014, 66 contracts were issued for the Intellitube. The totaled requisitioned was 341 LED bulbs for $54,167.85 or $158.85 per unit (DLA Internet Bid Board System Awards, 2014). DLA Transaction Services list the same item for $230.17 for issue to sailor Jones (DAASC Inquiry System (DAASINQ), 2014). The mark-up for a single Intellitube light bulb from DLA is $71.32. The fluorescent bulb sailor Jones would be replacing NSN 6240-00-152-2996 is listed by DLA Transaction Services for $39.98 per box of 30 (DAASC Inquiry System (DAASINQ), 2014). The last procurement by DLA for the fluorescent bulb was Jan. 10, 2013. DLA purchased 4419 boxes at $28.02 per box (DLA Internet Bid Board System

Awards, 2014). The mark-up for fluorescent light bulbs for this is $11.96 for a box of 30, which is $.40 per bulb. Further research for the cause to the mark-up difference on similar or substitute items is warranted. DLA's mark-ups do not reflect the cost of actually handling the different bulbs, potentially distorting decision making.

2. NAVSEA

Installing new technology with minimal disruption to a ships schedule requires coordination. Perceived values this distributor started asking is, "who should get the upgrade, when should they get it, what types of fixtures should be replaced, how many should fixtures should be replaced, where should these fixtures go, who should replace the fixtures and when should the installation take place?" These questions from the distribution link can provide qualitative and quantitative values.

The Naval Sea Systems Command has many programs aimed at reducing the U.S. Navy's energy consumption. LED, solid state lighting is just one in a list that are being implemented on various ships. Specifically, "SEA 21 plans to install… solid state lighting in five ships"(McCoy 2012), three as of now that have all IntelliTubes installed in all fixtures, the *USS Pinchney*, *USS Forrest Sherman* and *USS Preble*. None of the fixtures on the first two ships, however, have been changed to the new LED fixtures, just the bulbs were changed. The USS Preble and the USS Chafee has all new fixtures as of 2012. Many other ships have a mixture of fixtures and bulbs that have been changed.

"The longer lifespan also results in a huge amount of savings in regards to maintenance…LEDs last 50 times longer than the incandescent meaning the lights only need to be replaced every six years compared to what was every other month," said Ben Hatch, NAVSSES Philadelphia Code 938 (Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility Public Affairs, 2011).

NAVSEA was involved with the $23M contract (N65540-11-D-0009) awarded to Energy Focus to "design, qualify and then supply the U.S. Navy with LED lights." (*Energy Focus to develop Navy LED lighting*, 2013) There were numerous design specifications, qualifications, engineering development and tests to have the lamps approved to meet the MIL-SPECS. "Additionally, the M1 IntelliTube is a retrofit lamp,

which works with line power or any of the legacy ballasts." (*LED/IntelliTube NAVSEA: LED Fluorescent tube replacement*, 2011) That means it must work without rewiring the fixture around the ballast.

NAVSEA 05, NAVSEA 21, NAVSSES, PEO Ships and NAVSEA NSWCCD Philadelphia work in-conjunction to schedule the implementation for this upgrade. The first consideration was the CBA and the payback period for the ship class. These departments work from the same CBA, leaving no misunderstanding of the payback period. This creates a consistency between departments and codes so values are communal. For example the Fleet Readiness R&D Program Project Plan for the DDG-51 Class SSL Initiative (Griggel, 2011), NSWCCD produced, clearly states needs and specifications for the use of LEDs on DDG-51 class ships. Submitted by Richard Griggel this document was the one that stated the actual need of the Navy, with a problem statement, impact statement and the proposed solution including the technical description. The problem statement does not focus on the energy savings that the LED produce, but instead on the maintenance associated with the shipboard lighting system and the specific purpose of the proposal "is to complete the development, testing, evaluation, and military qualification of LED-based replacements for the legacy fixtures…" (Griggel, 2011). The payback for replacing all the DDG-51 class fixtures with SSL is FY18, which is a 6 year payback. Full implementation would be in FY19. Figure 7 shows the projected savings.

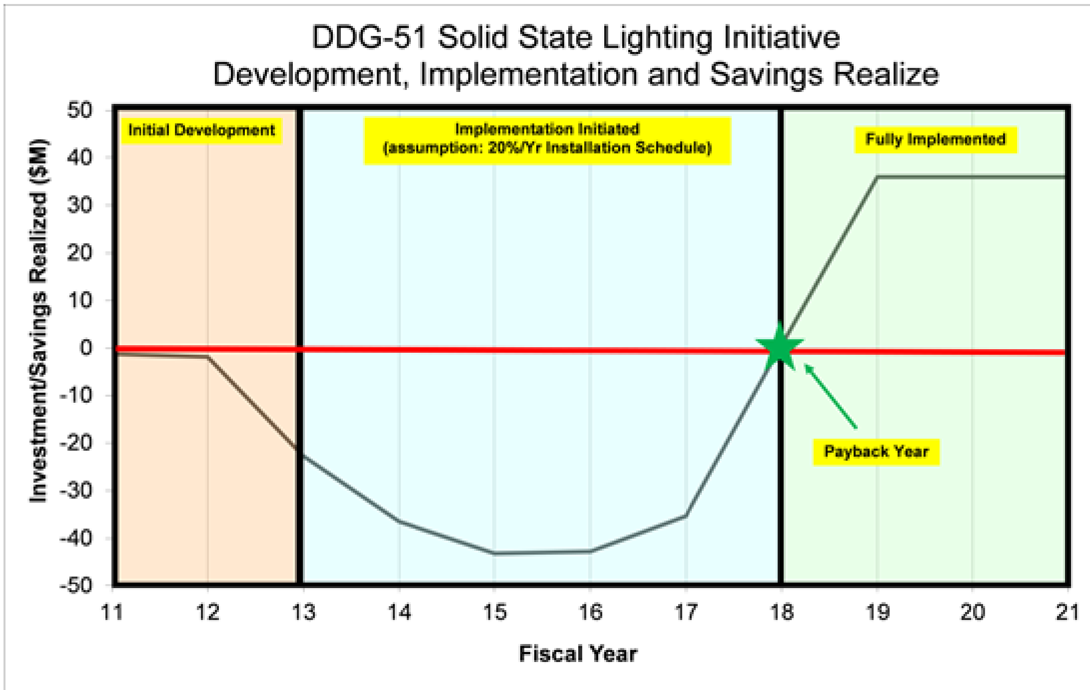

Figure 7. SSL Initiative savings realized from the final DDG-51 Proposal (from Griggel, 2011)

In considering the valuation of implementing LED lights for the different commands and codes within the Navy we are categorizing this as "group think" mentality. Each code has their own specialty and mission, but each division or command appeared to be working from the same worksheet.

The factors considered in the CBA were the power (watts), energy/yr (kW-hr/yr), cost / yr, barrel (BBL)/yr and shore power (kW/yr) (Vigliotti & Hatch, 2011). These variables are considered when comparing a ship with fluorescent fixtures verse LED fixtures. The savings are calculated per year per ship. The underway and inport days were taken into consideration for the energy consumed on shore verses BBLs consumed underway. The cost of BBL's was also estimated at $128 as well as the number of fixtures. (Vigliotti & Hatch, 2011) The FBCF was not considered initially. NAVSEA 05C, appears to be using the FBCF of $4.86/gallon. This equates to $1.25/gallon of the added burden associated with delivering fuel to a ship that is underway. (L. Wallington, personal communication, June 3, 2014) There are six variations of the incandescent and fluorescent fixtures considered in the CBA. These fixtures are being weighted by the

amount the lights are expected to be on. A berthing light is expected to be on only 20 percent of the time, where all other fixtures, globes and overheads are weighted at 80 percent. This affects how much savings will be consumed, when some overhead lights are expected to remain on 100 percent of the time, like in the engineering spaces or in passageways. The fixtures will remain on in either a white light or red light due to darken-ship mandate.

There are several variable costs that go into the installation price of lights that may not have been as apparent and some prices that have changed during the Cizek's CBA. The price for installing are variable per fixture, ships drawings that are required to be updated, and the labor, which was considered during Cizek's CBA. The price of the just the T12 replacement has dropped considerably. The price per fixture depends on the type of fixture symbols 331.1, 77.4 or 333.1 are $157, $320 and $480 respectively. The labor rate is considered $220 for each fixture to remove the old fixture, install the new fixture and test in place. Each fixture change takes an estimated two hours to change. (B. Hatch, personal communication, Feb 25, 2014) Then each ship must receive updated ship designs which can cost up to $300 per fixture depending on the ship class and amount of fixtures being replaced. If the ship has already been in the design phase like the newer DDG's, the redesign is added money to a program that has high oversight already. Having a ship receive new ships drawing for lights after the ship has been in-service can cost a minimum of $125,000 per ship. This adds to the investment cost which may not have been considered by any other stakeholder within the adoption chain.

From discussions within the various codes and echelons within NAVSEA, each valued implementing LED lights. The evaluation and reasoning for implementing LED technology did not stray far from the break-even analysis. A common theme, which soon became our perception, was the unanticipated obstacles that were faced when trying to upgrade a lighting fixture.

The devil is in the details, as the following example shows. A major barrier and lesson learned during the installation of berthing lights is an intangible cost and highly never expected by anyone. On ships, the berthing lights are affixed to the bunk above. On ships, a bunk or rack where a sailor sleeps is considered personal space for sailors.

They are locked and only allowed to be opened by the sailor and the sailor must remain there during the entirety of the work being completed, until the personal space can be locked again. Each installation of a berthing light can take up to 2 hours (B. Hatch, personal communication, Feb 25, 2014). This means a major inconvenience to the schedule of the sailor as well as the contractors. Each sailor losses productivity or time they can be training. These installations are normally scheduled during maintenance availabilities. A great time for an XO to send his sailors to schools or allow his sailors to take leave is during maintenance availabilities. Scheduling installations for berthing lights had more barriers than initially expected. This unforeseen cost may not have persuaded one not to complete the installation; this proved how much coordination cost is involved in installation in a berthing compartment.

There was an understanding that the current lighting technology, fluorescent, halogen and incandescent are out dated and will soon be phased out. Alternative lighting sources have been discussed within NAVSEA and have even been tested in well-decks of some amphibious ships. Remote lighting was considered premature in its life (T. Schuler, personal communication, April 15, 2014). Remote lighting using fiber-optic cables with one really bright bulb provides light to specific locations. There can be one main bulb with a back-up if necessary, and the light bulb could feed multiple lighting fixtures. This alternative reduces the maintenance requirement substantially. A maintenance man only needs to replace one light bulb for a possible 10 fixtures or more.

It is evident that some aspects of the technology adoption chain were understood by NAVSEA representatives. Some barriers that were understood were the specifications that were mandated by light-bulbs. Each representative understood the necessity and did not downplay the need for such requirements. A common question raised, was whether all the stringent specifications for lights was necessary. The specifications and requirements for lighting are old and need to be revisited and researched further. Every conversation believed that having more suppliers would help drive down the cost of LED lights for Navy ships. There was a realization that cost drivers in the equation were a limiting factor for businesses to want to supply the Navy LED lights. The stringent specifications limits innovation to current lighting fixtures ultimately created a cost

driving mechanism. This limits the supply market due to high certification requirements (T. Schuler, personal communication, April 15, 2014).

The initial crew feedback to NAVSEA was positive, “The new lighting fixtures illuminate the well deck wing walls and immediate vicinity vastly more effectively than did their original counterparts…it is with my strangest recommendation that I endorse this program for Fleet-wide consideration and approval” CDR Victor V. Cooper, CO, Pearl Harbor (B. Hatch, personal communication, February 26, 2014).

Within NAVSEA, code 05C is the cost estimating division. This division conducts internal cost estimating for all acquisition categories 1C (ACAT 1C). These programs need to be greater than $365 million of RDT&E or a procurement price of $2.19B, or designated by USD (AT&L). Of course changing the light bulbs on ships did not meet the criteria for ACAT 1C. NAVSEA 05C has been requested to provide a special studies for solid state lighting by Rear Admiral Fuller, the Navy’s Chief Engineer and NAVSEA Deputy Commander for Ship Design, Integration and Naval Engineering (SEA 05). NAVSEA 05C will analyze the status quo cost vs the investment cost. They conduct a business case analysis, which is differs from a cost benefit analysis (L. Wallington, personal communication, April 25, 2014). With discussing how to provide a good cost estimate, we were cautioned on making assumptions.

3. U.S. SHIPBUILDERS NSRP

The National Shipbuilding Research Program is a structured collaboration of the major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers (Energy Focus Inc. Under Contract to Develop an “All Platform” LED Lighting System for New Navy Ships, 2013). In 2012, NSRP selected nine major research and development projects as part of the Program's continuing mission to reduce costs associated with U.S. Shipbuilding and repair. The All Platform Affordable LED (APALED) lighting was one of the nine that were valued at approximately $12 mission in both Navy funding and Industry cost share (SCRA, 2014). The goal of the program is to develop, build and test a LED system to replace the Navy's current fluorescent fixtures.

Energy Focus was awarded this contract to develop the APALED for the NSRP. “APALED utilizes Energy Focus' M1 IntelliTube lamp, building a new fixture set around it which provides additional benefits to the shipbuilder including recued cost, complexity, wiring, size and weight.” (Energy Focus Inc. Under Contract to Develop an "All Platform" LED Lighting System for New Navy Ships, 2013).

4. EXTERNAL VALUES

OPNAV 45E champions for energy programs to be researched developed and transitioned to the fleet. N45E was formed to push energy initiatives. N45E appears to be a key lobbyist for Navy Energy innovation and distribution process. They are a source of funding for LED lights to NAVSEA. Some initiatives need more coaxing than others, like LED lights. N45E can fund or lobby certain projects that prove a high return in capability or a decrease dependency in the energy program. One major competitor of funding to LED lights is the stern-flap that is placed on surface ships. The stern-flap extends the bottom of the ship. This appears to be a simple and relatively easy concept. There are minimal scheduling conflicts with other maintenance as it not near any equipment. It is welding on externally and does not require ships force assistance. The stern-flap has proven to save approximately 3.4% of fuel (2,000-4,900 bbl/ship/yr) (Green Fleet Stern Flaps). LED lighting has been estimated to save only .1 or .6% depending on ship class, which is 300-485 bbls (Green Fleet Solid State Lighting). LED lights will not be able to contend against another program when funding cuts are on the table and the value is solely fuel savings.

5. SUBMARINE COMMUNITY

"The submarine community is pushing to adopt LEDs because fluorescents contain mercury," said Edward Markey, NAVSEA Philadelphia Electrical Powergroup and TechSolutions technical point of contact on the SSL project. “Hazardous materials require special disposal procedures, costing the Navy time, money and space” (Ottman, 2011). This cost and others will be quantified later in the following chapters.

6. MSC

Military Sealift Command has vested interest in the new LED lights. In 2010, The USNS Comfort's Chief Engineer Joseph Watts requested a life cycle lighting analysis. Students at NPS conducted the analysis and found that buying Energy Focus lighting could save taxpayers up to $6 million in three years. (Stewart, 2013) As part of the fleet of ships that supports the warfighter, MSC has a massive interest in LED lighting and other energy saving projects (Bowers, Goering, & Leiderman, 2012). This study did not include DLA's price markup, MIL-SPEC, and used COTS as a basis for the pricing, therefore the total savings will be much lower for the Navy if the Navy continues to use MIL-SPEC and DLA.

E. END-USER

The sailor who is trying to read a book in his bed, maintaining a helicopter in the hanger bay or an engineman looking for leaks around an engine are examples of the end-user. The end-users initial perception appears to value reduced noise and maintenance requirements created by troublesome fluorescent lights, fixtures, ballast and starters. This perceived value comes from the initial request to ONR from a submariner. Other values of lighting that are necessary to the end-user may appear in other aspects such as productivity from the work environment and headaches (Freymiller, 2009; Steven & Levitt, 2009). These aspects may not be as apparent to the user initially, but through studies, standards or other indirect methods, their perceptions may come to light.

1. VALUATION OF COST VERSES TIME

There is a difference between the perceived values of the maintenance man or the supervisor creating a daily work schedule verses the maintenance cost that is being considered in the cost benefit analysis. A maintenance person will get paid based off of an 8 hour workday regardless if they work 9.5 hour days inport or 18 hour days underway. A supervisor in the Navy creates a schedule based on the labor hours required to complete the job, not based off of the cost of the maintainer. A supervisor does not value if a newly frocked E-5 verses the E-2 changes a light bulb. The supervisor and maintenance man value the amount of time required to change every light bulb. The

misalignment in the valuation of time verses money is an important calculation and should be considered.

The frequency of when a light bulb is required to be changed is highly valued as well. A supervisor can have the maintenance person change bulbs in batches. This saves time and prevents some redundant steps such as gathering tools and parts (The Advantages of Group Relamping: Ideas That Build Business, 2008.) The longevity of a light bulb is valued high as this will change the frequency of changing a light bulb. Appendix B illustrates that the supply department issued boxes of fluorescent bulbs instead of single bulbs. This however does not provide enough information to make a clear assumption on the number of bulbs that were changed in batches. A simple assumption could be made that 30 fluorescent bulbs were changed 12 times throughout the year. We cannot speculate if these 30 bulbs were changed in the same fixture or on the same day. As on most ships, light bulbs are issued on a case by case basis, unless an inspection or visitors are coming onboard. Therefore, the only logical conjecture that can be made is that the only batch re-lamping might have been during the issuance of the 300 bulbs twice on the same day.

The manning requirement for a ship is dependent upon the mission and personal required to support and complete those missions. Optimal manning has decreased manning from ships but the requirements and tasking have not changed. Sailors are required to complete all in-rate training on top of general military training and these all take time. Yes, these requirements cost money, but time is poses a higher value to the sailor, not the money spent on training. The value of money verse the value of time must be differentiated and expressed in the CBA or business case analysis.

In a private company, the labor rate verses hours spent can be watched closely using time cards or production output. The labor variance expresses how efficient a production line is, but the Navy does not pay by the hour or by task. The Navy pays the maintainer by a straight-rate salary verses an hourly wage. The incentive should be to save the maintenance person’s time verses money on maintenance hours due to the high demand on the time.

V. QUANTIFYING TANGIBLES AND INTANGIBLES

It is imperative we attempt to quantify both the tangible and intangible costs, and the benefits of LED lighting or its alternatives. Placing value on both allows decision makers to form better cognizant decisions. Take a Foot-Candle (ft-candles) for instance. A Ft-Candle is quantifiable and can be measured, but a decision maker may not be able to visualize the actual difference. Figure 8 demonstrates the visible difference between a fluorescent fixture and a LED fixture provided by 3M. This demonstration draws a definitive conclusion how a 12.6 Ft-Candles compares to 22.8 Ft Candles fixture.

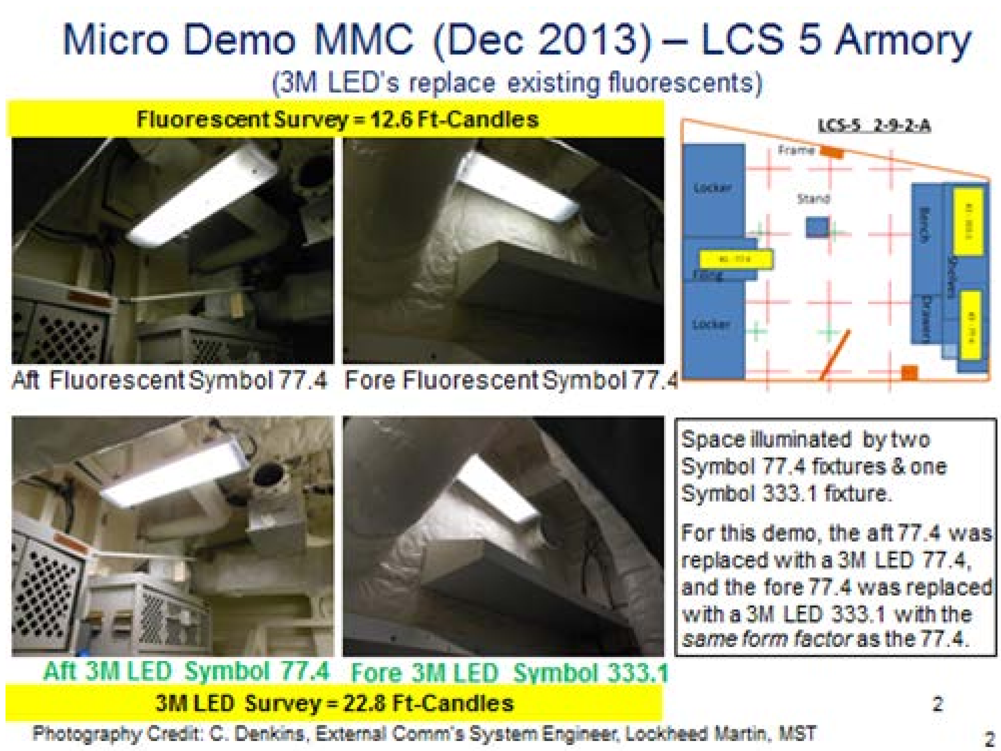

Figure 8. LCS-5 Armory space with fluorescent light before and 3M LED fixtures (from 3M TOC of Lights, 2013)

How can this be completed? One can attempt to make educated guesses placing an actual price or value to intangibles or conduct a better, more in-depth analysis to include the intangible benefits. However, a more robust analysis costs more time and money to conduct. Everything has a cost or is valued in some aspect. There are costs

associated for everything from training, storage space, to sitting down at a computer to order parts, having supervisors there and even maintaining the proper tools. All these cost if properly expressed, will further assist managers in outlining all the benefits that will come with the possible change or status quo.

To quantify some of the tangibles and intangibles and place value to them, we are going to perform some back-of-the-napkin math and make some educated guesses that are informed by the best information we have available.

As a disclaimer for us and all cost estimators, there are no perfect answers when determining a cost for a product. The perception of completeness and thoroughness by corroborated evidence (if possible) performed by the one completing the calculation is sufficient and defensible.

A. FULL-TIME PERSON

1. Full-Time Equivalent

We will attempt to quantify how many full-time equivalent (FTE) sailors are required to change only T12 CFL bulbs throughout a year. A FTE is considered to be one person working a full time rate for a year. Therefore if a job requires two people at 4 hours each for five days a week, then the task requires one FTE person for a given year.

The maintenance man in the equation is very important. Every stakeholder is considered with the amount of time a sailor consumed just changing light bulbs. Sailors are not primarily recruited to change light bulbs. The amount of time actually consumed must be taken into consideration. Comparing the figures for a maintenance person E-1 thru E-4 between FY10 and FY15 shows minimal change with the percent difference. The Annual DOD Composite Rate for E-1 thru E-4 are actually increasing at a slower rate than the actual inflation rate. This is a cost saving factor, however is minimal in the overall picture and is not relied upon or guaranteed will continue down this path.

FTE are considered when drafting contracts for maintenance work completed on a ship. Certain maintenance contracts are based on the number of labor hours and work experience with a cap designated for the maximum wage for the job. Assume a contract

stipulates the job requires a maximum of 40 hours of direct labors and must be completed within one week. The company receiving the contract can pay 8 people, 1 hour a day, for 5 days each to complete the same task in the contract. If the job actually requires 40 hours of labor and is a 2 person job, then 20 hours is actually expended not 40 hours. The supervisor and maintenance personnel both know their allotted time and task that is required to be completed. The Navy also creates these stipulations on labor hours and wages, so there is not an overpayment or wasteful spending. Is it feasible for the Navy to discover the FTE sailors that it takes to maintain a ship or submarine with all the requirements? It may be difficult, maybe, but possible.

The Office of the Under Secretary Of Defense uses .00055 as a multiple to determine the hourly rate of sailors from the annual wage rate. To keep consistency the FTE sailors required to perform a task throughout the course of a year, we use the same multiple. .00055 depicts an eight-hour workday, five days a week for 45.45 weeks in a year. The true number of working hours on a ship varies between inport or underway. However, typical working hours range from 9 to 12 hours inport and 12 to 18 hours underway. The disparity between these numbers show either a complete lack of the workers efficiency on ships or too many requirements attempted to be placed into the assumed eight-hour workday.

a. Changing a Light Bulb Takes How Long on a Ship?

A key data point for this study is contained in Appendix A is "How long does it take to change a light bulb in your garage?" To determine the amount of FTE sailors required to change only T12 fluorescent light bulbs, NSN 6240-00-152-2996, for one year period, we used Appendix B and C as a basis for the variables. During the one year period, CVN 70's supply department issued 3900 T12 fluorescent bulbs 46 times, requisitioned 4320 bulbs 10 times and received 7 shipments of 3480 bulbs.

We will compare four different lengths of average times that are expected for a maintenance person when replacing a T12 light fluorescent bulb. Our baseline assumption for the nominal time to replace a bulb is about .5 hours, which is erring on the low side. This conservative assumption would be true if the maintenance man walked

from the electrician shop, bulb and tools in hand, replaced the light bulb and walked casually back to the electricians shop. There were no other requirements, and the light bulb was disposed of in a garbage can in the shop.

Direct Labor Hours	Assumptions Based on:
0.5	Supervisors expectation
0.75	Comparison purposes
1.42	Study from CVN 73
4	Estimated w/tag-out

Table 3. Direct labor hour assumptions

According to a survey completed on *USS George Washington* in 2004, it required approximately 86 minutes (1.42 hrs) on average per person to replace a bulb, ballast and/or starter for the fluorescent T12 fixtures. When completing this task, two people were utilized making it an average of 2.84 hrs per maintenance requirement (Cizek, 2009). After informal discussions with NAVSEA 05C, 4 hours may be considered in their calculation based on system matter experts (SME) of electrical lighting (L. Wallington, personal communication, May 11, 2014). This figure is extremely high, but assumes every step of the maintenance man requirements. The time the maintainer leaves the work center to perform the task until the maintenance man is ready to work on the next task. The total time is considered to be estimated as the required time to "change a light bulb". Some of the steps considered are: tagging out the light and tagging the light for normal operation, walking to the storeroom, finding tools, changing the bulb, walking to HAZMAT and replacing tools. The major time consuming item in the steps above is tagging out and tagging in a piece of equipment. Tagging out a light-bulb alone can require 1 hour of work. The maintenance person must find the associated circuits in an approved ships drawing and the correct breakers and switches to isolate them. The documents must be printed and danger tags must be approved by the Engineering Duty Officer (inport) or Engineering Officer of the Watch (underway). Once approved to secure the equipment, the maintenance person will secure the equipment properly, hang the correct danger tag with the equipment or switch. Once that is complete, the maintenance person will request a qualified independent signer to follow the circuit and

sign all the tags originally hung once verified they are correct. All this takes time, for the maintenance person, to the supervisor through the second signer. After the job of replacing the light fixture is complete, the maintenance person must complete the task in reverse order with the exception of the second signer. The breakdown was not explicit on the usage of the 4 hours from the personal communication of NAVSEA 05C, L. Wallington, we are assuming the maintenance person alone is consuming the 4 hours, not a total of supervisor and second reviewer of the danger tagout (personal communication, May 11, 2014).

Table 4 illustrates the estimated FTE sailors required to complete the maintenance on CVN 70 to change 3900 bulbs over the period of a year. The initial 1.07 FTE is considered when only one maintenance person is required to change a light bulb. All jobs that involve a ladder, lift, or electrical equipment require multiple people; therefore, there is a FTE with two people performing each task. Further in the chapter we will sum all FTE sailors estimated to change a light bulb using the FTE with two sailors performing the task.

Direct Labor Hours				
bulbs /yr	3900			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	1950	2925	5538	15600
Full-Time Equivalent	1.0725	1.60875	3.0459	8.58
DL Maintenance Cost	$ 57,213.00	$ 85,819.50	$ 162,484.92	$ 457,704.00
Full-Time Equivalent w/2 performing task	2.145	3.2175	6.0918	17.16
DL Maintenance Cost w/2 performing task	$ 114,426.00	$ 171,639.00	$ 324,969.84	$ 915,408.00

Table 4. Number of T12, Fluorescent light bulbs, NIIN 001522996 replaced on CVN 70

Looking at Table 4, even when erring on the low side using .5 hrs, CVN 70 requires a minimum of 2.1 FTE sailors dedicated to changing only T12 CFL bulbs on CVN 70. If we use *USS George Washington's* survey time of 1.42 hours, this would mean that they provided 6.1 FTE maintainers for the entire year. These 6.1 FTE's are entirely consumed for only T12 CFL lamp maintenance. This does not include the indirect labor that is associated with the process of changing these light bulbs.

The 6.1 FTE sailors removed from a crew size that ranges from approximately 2500 sailors in direct support for the ship and an augment with 3000 sailors to support aircraft may seem justifiable and acceptable. However, even those 6.1 sailors were most likely not trained through their rate training, to change only one specific type of light bulb. This is just a sample which can be plausible and extrapolated to compare other sizes of fluorescent bulbs such as globe fixtures and berthing lights.

Considering T12 CFL bulbs are becoming obsolete, the stockpile and warehouses must move any and all stock that they hold onto. This includes light bulbs with lower efficacy and expected life span that was provided to the Navy in the past. After conversations with industry specialist and NAVSEA system matter experts, it is apparent the life expectancy of the current T12 CFL's on ships might only average 6-8 months, instead of the 1-1.2 years that was forecasted. This decrease in efficacy is due to the bulbs becoming obsolete, a decrease in the manufacturing quality (T. Schuler, personal communication, April 15, 2014; C. Bruzzone, personal communication, April 25, 2014). Using the estimated numbers of bulbs on a CVN compared to the number of bulbs on CVN 70, we estimated 16 percent of the bulbs were replaced throughout the year. This estimate was only using one of the T12 NIIN's, in which 3900 bulbs were checked out from supply within a year timeframe. Cross-referenced or similar NIIN's were not analyzed. Further analysis is needed to determine the full scope of how many T12 bulbs are changed on a ship in a given year due to fixture location and quantity of bulbs in fixtures. Some bulbs may not be replaced due to the back-up bulb in the fixture. This redundancy creates a skewed time frame for bulb replacement.

Using the current life-expectancy of fluorescent bulbs from industry experts and NAVSEA, we will consider replacing 100 percent of the bulbs throughout the year. Table 5 shows how many direct labor hours are required on a DDG to replace 100 percent of the estimated T12 light bulbs. In direct labor hours for a DDG using the two man rule, this will amount to 1.6 FTE sailors when using .5 hrs required replacing a single bulb. Using the USS George Washington (CVN 73) survey and NAVSEA 05C, 4.5 and 12.6 FTE sailors are required respectively. A DDG is manned with approximately 250 enlisted sailors, which 4.5 sailors can be expected to change only T12

light bulbs. This is not to explicitly mean that 5 sailors will be devoted to changing only light bulbs. On most ships changing light bulbs is a combined effort, which any sailor can change a light bulb. Therefore this does negate a possible batch re-lamping assumption.

Direct Labor Hours				
bulbs /yr	2856			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	1428	2142	4055.52	11424
Full-Time equivalent	0.7854	1.1781	2.230536	6.2832
DL Maintenance Cost	$ 41,897.52	$ 62,846.28	$ 118,988.96	$ 335,180.16
Full-Time equivalent w/2 performing task	1.5708	2.3562	4.461072	12.5664
DL Maintenance Cost w/2 performing task	$ 83,795.04	$ 125,692.56	$ 237,977.91	$ 670,360.32

Table 5. Direct labor hours for maintenance man on DDG, replacing 100 percent of T12 bulbs

The indirect labor and associated cost with the lights are just as valuable as the direct costs. Indirect costs necessary to value are the supply personnel that are required to order, track and process the bulbs. Besides a dollar value of their labor, they add to the FTE sailor required to change a light bulb.

2. TRAINING AND QUALIFICATION

Every sailor, officer and enlisted, assigned to a ship requires certain qualifications and basic training. This training assists in the maintenance process, to include changing a light bulb. Before the maintenance man picks up any screw driver, checks out any tools, or tag-out a piece of equipment they must complete the personnel qualification standard (PQS) for maintenance and material-management (3M). Electrical training on the shock hazards of starters is also part of the sailor's command indoctrination and annual training requirements via GMT. HAZMAT training is included to ensure that personnel are aware that CFL bulbs contain mercury, and they are disposed of properly and provides the necessary steps to combat a HAZMAT spill or incident if a fluorescent bulb breaks. These training requirements are combined with other maintenance training requirements, but it is still part of the overhead that needs considering for lights.

Having the proper amount of FTE sailors trained to complete a task is dependent upon the technical expertise and amount of depth that is required. Changing a light bulb is not generally a daunting task, but it still requires trained personnel, with the proper PQS and experience to conduct all steps in changing a light, for example, trained to use a lift to get the overhead lights in the hanger bay.

Training requirements are a daily routine on a ship. Some are required quarterly, semi-annual or annual training for sailor's onboard ships, which can become overbearing and monotonous. The time spent training can be valued more than the cost actual cost of training. For instance, to train approximately 250 enlisted personnel, E-1 thru E-4 on a DDG, one half-hour annually on CFL or mercury alone, will cost the navy $3,667.50. The cost of training sailors on mercury exposer due to CFL bulbs is not substantial, but the opportunity cost it poses is much higher. It adds a negative weighted value to the sailors' efficiency due to lost productivity when attending required training.

As managers scheduling and accounting for time training individuals on a monthly or annual basis is important. Table 6 illustrates the estimated time required to train each FTE sailors to complete the task of changing light bulbs. Taking the number of FTE sailors expected to change light bulbs for a predetermined hour of maintenance will provides an estimated amount of hours expected in the training process. The expected hours to be trained annually will then be added to the direct maintenance hours and all other indirect hours expected to change light bulbs through the year to create the base line overhead. The PQS states that at minimum, an E-5 must be the qualifying signature for each line item. We will consider an E-5 must also be expended for the total hours needed to train all the trainees. Once the PQS is complete, the administrative burden requires time to review, sign, route appropriately and input into a database. This training process and requirement takes time, for the maintenance person and the supervisors. The supervisors, E-5 thru 0-5, must be qualified in certain 3M PQS's. Therefore they are included in the total cost and estimated FTE. Similar to the 3M PQS 301, which is for the maintenance person, the other PQS's require an E-5 minimum to be the signing person for each line item. 3 of the 3M PQS's have a minimum of 8 weeks to

complete and 3 other PQS's have a minimum of 4 weeks to complete. The training hours per year are estimated for light bulbs only.

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		2.145	3.2175	6.0918	17.16
3M PQS 301	40	85.80	128.70	243.67	686.40
Maintenance Man 3M PQS	40	85.80	128.70	243.67	686.40
DCPO PQS	40	85.80	128.70	243.67	686.40
Electrical Training Annual	1	2.15	3.22	6.09	17.16
HAZMAT	1	2.15	3.22	6.09	17.16
JLG (jack lift) / Harness	1	2.15	3.22	6.09	17.16
Total HRS spent training maintenance man		263.84	395.75	749.29	2110.68
Full-Time Maintenance Person to be trained		0.1451093	0.2176639	0.4121103	1.1608740
3M PQS 302-307 (if supervisor completes concurrently)	50	0.20	0.29	0.55	1.56
16 Supervisors (2 Divission+CMC/XO/CO)	100	0.393512047	0.587610415	1.107794044	3.110889209
Full-Time Supervisors Trained		0.000216	0.000323186	0.000609287	0.001710989
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	32.407627	48.61111454	92.03646115	259.2564526
Full-Time Trainers		0.017824195	0.026736113	0.050620054	0.142591049
Cost for Maintenance Man Training		$ 7,740.92	$ 11,611.38	$ 21,984.21	$ 61,927.35
Cost for Supervisors Training & Trainers		$ 23,363.50	$ 35,043.12	$ 66,344.51	$ 186,878.21
Cost for Training		$ 31,104.41	$ 46,654.50	$ 88,328.72	$ 248,805.56

Table 6. Estimated training time and cost required for maintenance personnel and supervisors

3. SUPPLY

It is important to determine the required logistical support necessary to sustain a piece of equipment. Supply personnel will ultimately perform the same job when a substitute product like LED replaces fluorescents bulbs. The different is in the frequency of work performed, if the substitute product merits it. A value can be estimated for the supply support either with a dollar value on their allotted time completing a task or by expressing the FTE sailor required to complete the specific tasks, similar to the maintenance man. To provide a FTE weight for the supply personnel or supply department, assumptions are made about the amount of time each task requires, ordering, tracking, processing once delivered and inventorying on an annual basis.

A supply person deals in units of issue. Appendix B illustrates the amount of times each task would be performed in a given year on CVN 70. The hours each task is performed is estimated. There is not any differentiation between receiving the unit of issue at the pier or during an underway replenishment. The assumption made is that all

tasks are done pier side. The storage of both the new and used bulbs may also be not necessarily kept in a supply storeroom. The electricians may be the custodians of the storeroom of the new bulbs, and the boatswain mates may be the custodians of the HAZMAT. We group both actions into the supply department for simplicity. The disposal price was calculated using $.05 per linear foot (Cizek, 2009). Table 7 expresses the supply departments total indirect cost and FTE required to sustain tasks performed on CVN 70. In total the indirect overhead cost or FTE supply person does not appear to be a significant amount.

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was	Hrs / Task	HRS / year	Price / year
Issued	46	0.2	9.2	$ 269.93
Receive/Store Used Bulbs	46	0.2	9.2	$ 269.93
Disposal off ship	3	2	6	$ 176.04
Disposal price	3900			$ 390.00
Requisitioned	10	0.2	2	$ 58.68
Receive New Bulbs	7	1	7	$ 205.38
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	53.4	
Full-Time Supply Person			0.02937	
Total Supply Indirect Cost				$ 1,956.76

Table 7. Estimated overhead and FTE for supply personnel on CVN 70

4. SUPERVISION

The Navy is not a production factory; however, the supervision overhead of a chain-of-command is difficult to quantify but still possible. The breakdown for the maintenance person's chain of command on average consists of the following people: work-center supervisor (WCS), leading petty officer (LPO), leading chief petty officer (LCPO), departmental LCPO, command master chief (CMC), division officer (DIVO), department head (DH), executive officer (XO) and commanding officer (CO).

As each of these people supervise the maintenance man in different capacities, it is still important to understand in total, how many FTE sailors are required to provide supervision for a single maintenance task, like changing a light bulb. An argument can be that changing a light bulb does not require any supervision at all. But a CO and XO

will still walk around daily and make small talk with the maintenance man. They may not provide any direct expertise or supervision, per se, but their presence is required in order to run and operate the ship, just like a chief executive officer or chief operating officer of a private company. It is also apparent that all of these supervisors will still show up to work if there were LED lights, CFL's or even Christmas lights up. The type or price of fixture does not matter, but the maintenance man's direct labor hours still require some sort of supervision regardless of the maintenance requirements.

Another assumption made is that all maintenance conducted requires the same amount of supervision. This is obviously not true, but to create a basic formula this will be the assumption. In order to quantify and place a value on supervision, we determined how many hours each person supervises a maintenance person per day. Table 8 compares the number of estimated FTE supervisors required for each estimated FTE maintenance person and FTE supply person.

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	1950	2925	5538	15600
Full-Time maintenance/supply person required per year		2.174	3.247	6.121	17.189
	HRS Supervising a person / da	Hrs / yr to be supervised			
WCS (E-5)	1	2.174	3.247	6.121	17.189
LPO (E-6)	0.75	1.631	2.435	4.591	12.892
LCPO (E-7)	0.5	1.087	1.623	3.061	8.595
Dept LCPO (E-8)	0.068	0.148	0.221	0.416	1.169
CMC (E-9)	0.0125	0.027	0.041	0.077	0.215
DIVO O-1 (ELECTRO)	0.445	0.968	1.445	2.724	7.649
DIVO O-2 (AUXO)	0.445	0.968	1.445	2.724	7.649
Department Head (0-3)	0.045	0.098	0.146	0.275	0.774
RA (0-4)	0.0125	0.027	0.041	0.077	0.215
RO (0-5)	0.0125	0.027	0.041	0.077	0.215
Total Hrs Spent Supervising	3.2905	7.155	10.684	20.142	56.562
Full-Time Supervisors		0.004	0.006	0.011	0.031
OVHD /yr for Light bulbs		$ 5,096.17	$ 7,609.84	$ 14,346.48	$ 40,287.54

Table 8. FTE supervisors and overhead cost required to supervisor FTE maintenance personnel and FTE supply personnel when changing T12 light bulbs on a CVN

An E-5 or work-center supervisor (WCS) will spend most of the day directly supervising the maintenance personnel. We assumed a direct supervision of one hour per day per person for the WCS. Changing light bulbs does not require much oversight, but a supervisor in some capacity is necessary. A commanding officer or 0-5 will spend little time directly supervising personnel, especially changing lights, but their time should be

valued on a per person basis as well. Regardless of time spent supervising individuals, all supervisors pay should be included as overhead, regardless of the amount of supervision required. The estimated total hours spent supervising is multiplied by the overhead rate of $712.28. The total overhead cost or FTE supervisor required to change this one type of bulb does not appear to be significant in isolation.

5. TOOLS

Every electrician is required to maintain certain tools to perform each task. Changing light bulbs are no different from any other requirement in this respect. A special tool may be required to reach ceiling and may require a scissor lift or JLG. Most ships do not have these lifts onboard, so they will rent from the base supply. If a JLG or scissor lift is rented, it costs are shared with other divisions, with other jobs, to minimize the waste, as they are normally rented on a daily basis. Table 9 shows an estimated price for a few items required for changing bulbs. The total price seems insignificant however tools are still a cost to the ship are required to maintain and keep on hand. Therefore, this price is considered in the final annual cost as overhead.

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Table 9. Estimated overhead cost for some tools to change a light bulb

6. SUMMATION OF TIME AND COST OF FTE SAILOR

Over the past decade the Navy has been shifting to minimal manning on ships. The outcome when assigning overhead cost to lights is not meant to determine if there is a need to further minimize supervisors or the number of overhead cost to this product. But determining the appropriate number of FTE sailors affected, can determine the amount of manning a ship requires or uses the manning for higher valued tasks. Consider

the LCS model where manning has increased slightly due to the taxing requirements put on the sailors. Changing light bulbs should not be a requirement that the maintenance person or supervisors should be concerned with. Every maintenance task requires a person to perform the task, training, qualifications, supervision, supplies and tools. These items must be evaluated along in the process to estimate the total overhead and costs to a project.

Table 10 illustrates the number of FTE sailors that are will be required to change 100 percent of the T12 lamps on a single ship comparing the four different direct labor hours. This is based off of the total lamps assuming two sailors on average change a bulb. For instance, if the average maintenance person takes only .5 hours to change a bulb on a CG, then only 1.3 FTE sailors will be employed changing only T12 bulbs. This also assumes that there is no batch re-lamping. If there is batch re-lamping, the required FTE's will be lower, as the direct labor hours will be reduced. (The Advantages of Group Relamping: Ideas That Build Business, 2008)

Class	0.5 DL Hours	0.75 DL Hrs	1.24 DL Hrs	4 DL Hrs
CG	1.331060404	1.984060266	3.734099895	10.47305847
FFG	0.589363094	0.873920456	1.636534185	4.573166155
MCM	0.245067561	0.358594092	0.662845194	1.834438991
LCS	0.551390068	0.817077678	1.529120473	4.271016607
PC	0.069041249	0.095125674	0.165031932	0.434223196
SSN	1.394907236	2.079623387	3.914662671	10.98093335
DDG	1.720705088	2.567263239	4.836039082	13.57251919
LPD	4.931544366	7.37310581	13.91649048	39.11340458
LSD	4.367066767	6.528220645	12.32011304	34.62322105
SSBN	2.797150741	4.1784396	7.880293741	22.13519476
LCC/Tender	4.905289593	7.333808825	13.84224037	38.90455884
LHA/LHD	10.35554158	15.49150554	29.25588896	82.25903703
CVN	14.27048611	21.35122179	40.3275934	113.4007856

Table 10. Total full-time equivalent sailors required to change all Fluorescent T12 lamps on a ship based on direct labor hours

Table 11 illustrates the summed cost of the FTE sailor to change 100 percent of the T12 light bulbs on a ship. This cost compares the direct maintenance hours as a basis adding in the supply cost, training and supervision required to change this single type of

bulb in a given year. The comparison illustrates the higher the number of hours used to change T12 light bulb, the more FTE sailors and higher cost are required.

Class	0.5 DL Hours	0.75 DL Hrs	1.24 DL Hrs	4 DL Hrs
CG	$ 89,704.52	$ 125,667.29	$ 233,766.16	$ 650,027.49
FFG	$ 39,985.50	$ 55,656.98	$ 102,763.16	$ 284,157.11
MCM	$ 16,156.59	$ 22,040.10	$ 39,845.21	$ 108,408.21
LCS	$ 75,923.81	$ 111,921.57	$ 208,395.59	$ 579,892.55
PC	$ 4,925.65	$ 6,277.47	$ 10,368.46	$ 26,121.84
SSN	$ 82,304.67	$ 115,247.41	$ 214,268.53	$ 595,573.74
DDG	$ 115,824.00	$ 162,446.65	$ 302,587.53	$ 842,234.54
LPD	$ 331,059.75	$ 465,524.28	$ 869,705.13	$ 2,426,103.03
LSD	$ 293,220.50	$ 412,242.10	$ 770,003.73	$ 2,147,653.00
SSBN	$ 187,982.58	$ 264,054.54	$ 492,715.79	$ 1,373,232.26
LCC/Tender	$ 313,037.90	$ 463,046.04	$ 865,067.86	$ 2,413,151.86
LHA/LHD	$ 694,652.57	$ 977,506.39	$ 1,827,723.90	$ 5,101,695.77
CVN	$ 909,673.27	$1,347,045.96	$ 2,519,204.77	$ 7,032,890.93

Table 11. Annual cost (direct labor, supply, training, supervisor and tools) to change 100 percent T12 light bulbs on a given ship

B. HEAT

Cizek's and Freymiller's theses' address heat as an added benefit but neither quantified it down into fuel savings. EFOI LED lights produce 63.5 less Btu per hour than a standard T-12 fluorescent (Bowers, Goering, & Leiderman, 2012). Using Cizek's operational cost and Conventional Ships Service Generator Fuel Consumption Table (Cizek, 2009), plus Bowers, Goering and Leiderman's thesis on Lifecycle cost of the Hospital-ship USNS Comfort (Bowers, Goering, & Leiderman, 2012) calculation of energy used to convert energy into heat was relatively easy. Table 12 illustrates the fuel savings by lowering the heat produced from the CFL bulbs.

The Difference in Heat produce between LEDs and fluorescents							
Ship Class	Number of fixture per ship class	LED watts/ship	Florescent Watts/ship	LED reduction from max load	Est Total Fuel Consumption w/ fluorescents at max load (gph)	Est Total Fuel Consumption w/ LED at max load (gph)	Fuel Saved (gph) or Fuel Used to Power Other Equipment
FFG	384	0.6912	2.688	4311.52929	71	69.57240446	1.42759554
CG	881	1.5858	6.167	8581.048263	147.2	140.3478116	6.852188404
MCM	153	0.2754	1.071	1116.024782	25	24.80055072	0.199449283
PC	35	0.063	0.245	149.7268279	11	10.97996738	0.020032621
LCS	502	0.9036	3.514	2920.97392	49	47.7092407	1.290759301
LPD	3335	6.003	23.345	9786.057002	147.2	120.0422992	27.15770078
San Antonio				10193.80938	150	122.3257125	27.67428748
DDG	1573	2.8314	11.011	8242.384886	147.2	134.8087839	12.39121609
LCC/Tend	3317	5.9706	23.219				
LSD	2919	5.2542	20.433	4366.931305	80.5	67.60345577	12.89654423
LHA/LHD	7015	12.627	49.105	3029.01354	140.2	81.66686505	58.53313495
SSN	696	1.2528	4.872				
SSBN	1864	3.3552	13.048				
CVN	9555	17.199	66.885				

Table 12. Fuel Savings due to Heat Reduction

C. WEIGHT

All LED fixtures available for shipboard use are almost identical in weight to the current T12 fluorescent fixture. How does weight of the LED replacement bulbs compare with an average CFL bulb? The retrofit using EFOI’s Intellitube bulb should be addressed. In comparison, the Intellitube weighs 1.012 lbs. against an average CFL bulb that weighs .35 lbs. The difference is a mere .662 lbs. Can the simple added weight of these light bulbs affect a ships performance? What does the increase in weight do to a ship? It depends on the placement and amount of weight. Added weight can disrupt the buoyancy and stability designed for the ship specifications. If the added weight is placed high in a compartment, it may disrupt the center of gravity and possibly adjust the righting arm during a roll. Adjusting the righting arm can extend the amount of time for a ship to become perpendicular again after the ship takes a roll, indirectly affecting the ships survivability and crew’s wellness due to being nauseous or sick.

Added weight can also increase the displacement of the ship, which in-turn can increase the fuel consumption and the efficiency of the ship. Increasing the displacement is comparable to ballasting a ship and increasing drag of the ship. The difference when you ballast a ship, you increase weight in the lower portion of a ship, increasing the ships stability.

To consider a worst case scenario, Table 13 illustrates the difference how changing all estimated T12 lamps for a ship class affects the displacement (long-tons). The difference is calculated using light ship displacement times the number of fixtures times .662/2240. .662/2240 converts the difference of the bulbs weight into long-tons.

Full Retrofit Calculations with Intellitube				New Displacement After Retrofit	
Class	Name	Light Displacement	# of Lamps	Change in Long-Tons	New Displacement
AUX	Blue Ridge	13038	8193	2.42	13040
	Emory S. Land	13991	8793	2.60	13994
DDG	Arleigh Burke	6691	2856	0.84	6692
SSN	Los Angeles	5700	1740	0.51	5701
	Seawolf	7568	2310	0.68	7569
	Virginia	5921	2018	0.60	5922
FFG	Perry	3144	960	0.28	3144
CG	Ticonderoga	7218	2203	0.65	7219
SSBN/SSGN	Ohio	15275	4660	1.38	15276
MCM	Avenger	1253	383	0.11	1253
LSD	Whidbey Island	11471	7210	2.13	11473
	Harpers Ferry	11604	7291	2.15	11606
CVN	Nimitz	78280	23888	7.06	78287
	Enterprise	75704	23100	6.83	75711
LPD	San Antonio	19013	8237	2.43	19015
LHA/LHD	Tarawa	25884	17327	5.12	25889
	Wasp	28050	17327	5.12	28055
LCS	Freedom	2135	904	0.27	2135
PC	Cyclone	288	88	0.03	288

Table 13. Comparison of a ship's light displacement before and after a complete retrofit of Intellitube light bulbs (after Cizek, 2009)

USS Pinchney (DDG 91) procured 3,500 EFOI Intellitube LED bulbs (Energy Focus Military Lighting Products, 2013). The fixtures were not replaced. If all of these Intellitube bulbs replaced a fluorescent bulb, the added weight after installation was approximately 1.034 long-tons.

Consider the perceived values that were discussed above, by Sailor Jones on a CVN or LHD, where only 7 and 40 fixtures were replaced respectively. Sailor Jones understands that CVN XY many not gain from all the T12 fixtures being replaced when certain values are or are not considered by the distributor, NAVSEA, and may never receive a full upgrade to LED fixtures. Sailor Jones on CVN XY can however purchase

IntelliTubes and complete the retrofit himself. There is a feasible solution to by-pass the distributor, NAVSEA, and buy through the other distributor, DLA. Let's say for instance Sailor Jones purchased 23,888 IntelliTubes, the total number of T12 lamps assumed for a Nimitz class CVN (Cizek, 2009). The sailor completes this purchase due to the concern of the amount of hours expended and number of personnel a year required to change these troublesome T12 light bulbs. This upgrade aligns with the sailors' values, but not the values considered by in the CBA. Sailor Jones' life will be easier, achieve other qualifications and complete other higher priority tasks. The drawback to this rogue sailor is that it will add approximately 7.06 long-tons to the ships displacement. Provided a CVN may not necessarily be concerned with the added fuel consumption this amount of displacement, there still may be added stress to the engineering dynamics and longevity of ships equipment. The current purchasing price set by DLA of $230.17 per Intellitube may be the constraining factor for Sailor Jones to purchase over $1.6 million of light bulb, but the option is available.

The added weight on a carrier may not pose much concern. A carrier is already 78,280 long-tons, what's another 7 long-tons? Adding over 2 long-tons to a Harpers Ferry class LSD may possibly restrict the ships mission due to the added draft. Amphibious ships manage their draft carefully depending upon their mission and the waters they are operating within. Deballasting the ship may not be an option with the added weight restricting the ship unnecessarily. Certain ports are extremely shallow requiring deballasted for safety and may only be navigated during higher-tides to prevent a soft-grounding. The effects of added the weight when considering a retrofit should be further researched.

D. SPACE

Space on ships is at a premium due to the limit space available. Every nook and cranny on a ship has something stored in it, whether the space is a dedicated store room or not. So the possibility of converting the light bulb store room into an engineering parts store room has the potential to have a very high opportunity cost. Take a CVN; it has a light bulb store room of 60x68x25. Currently, that room holds 42 box, sized 24x8x10, @

$32.25 a box, costing $1,354.50. However, calculate the cost by the amount of space it takes costs a little more. One box of lights is 1920 in^3 or 1.11 ft^3. Times that by the number of boxes, 42, and the cost per box, $32.25, to arrive at the total of $1,505. That is the value of the boxes in this room. The opportunity cost is what else can be stored in this room. Engineering parts, and general ship supplies, can run costs between $1 up to $6,000 plus and come is a wide range of sizes and weights. Even one large valve that costs over $6,000 and takes up less than a quarter of the space available can make a big difference in the opportunity costs. That is up to the different ships, because no two ships have the same store room dedicated to the same inventories.

The SSN and SSBN have an even greater premium on space. Figure 9 shows an electrician shop on a USCG Cutter (Kingsley, Fike, Reubelt, & Amerson, 2012). This illustrates the many ways that space is utilized to the fullest. Since space is a premium and further limited on submarines, removing the need to store a large number of replacement bulbs adds a higher value to implementing LED light bulbs.

Figure 9. Typical light bulb storage on ships and submarines (from Kingsley, Fike, Reubelt, & Amerson, 2012)

E. PRODUCTIVITY

The impacts of lighting on productivity are well-known. Lighting may also affect subjective elements such as morale, which is the most difficult to quantify (we will not

try to quantify it here. It is a very important subject that can make or break life on a ship, but is very hard to pin down).

We consider first studies on visual light vs productivity, second the USB adapter that EFOI has outfitted the new IntelliTube bunk lights with, third is the effects of electrical shock and finally the effects of headaches on productivity.

1. Hawthrone Experiments

The Hawthrone Experiments were conducted in the 1920 at the Hawthrone plant. The studies were known as the "Illumination Experiment." Figure 10 and Figure 11 shows a chart of Hawthrone experiment's raw data.

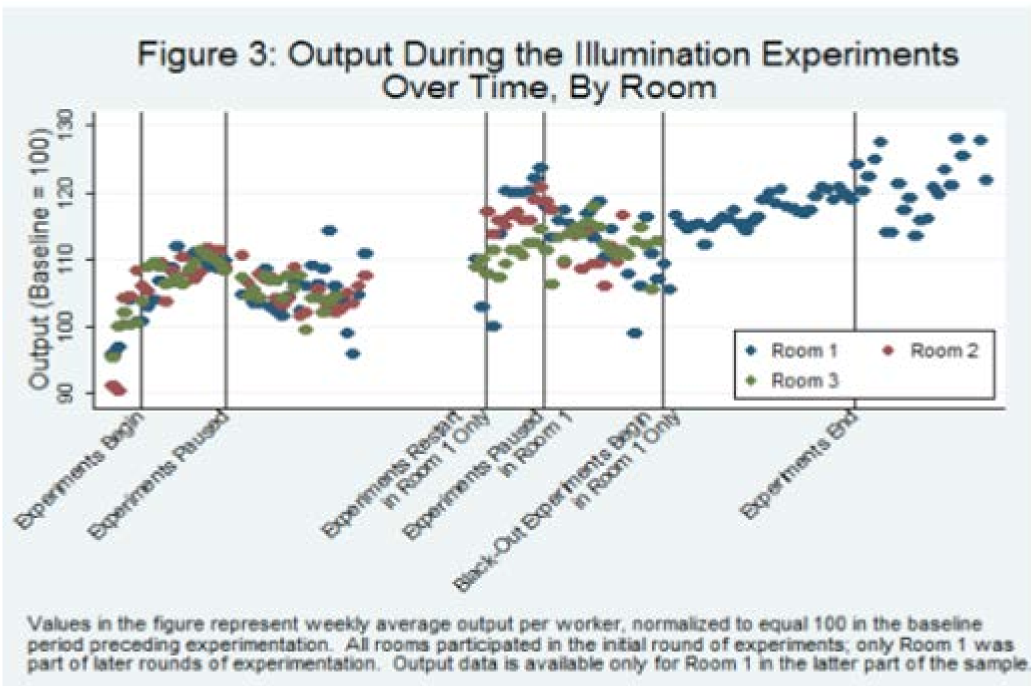

Figure 10. Original data from Illumination Experiments (from Levitt, 2009)

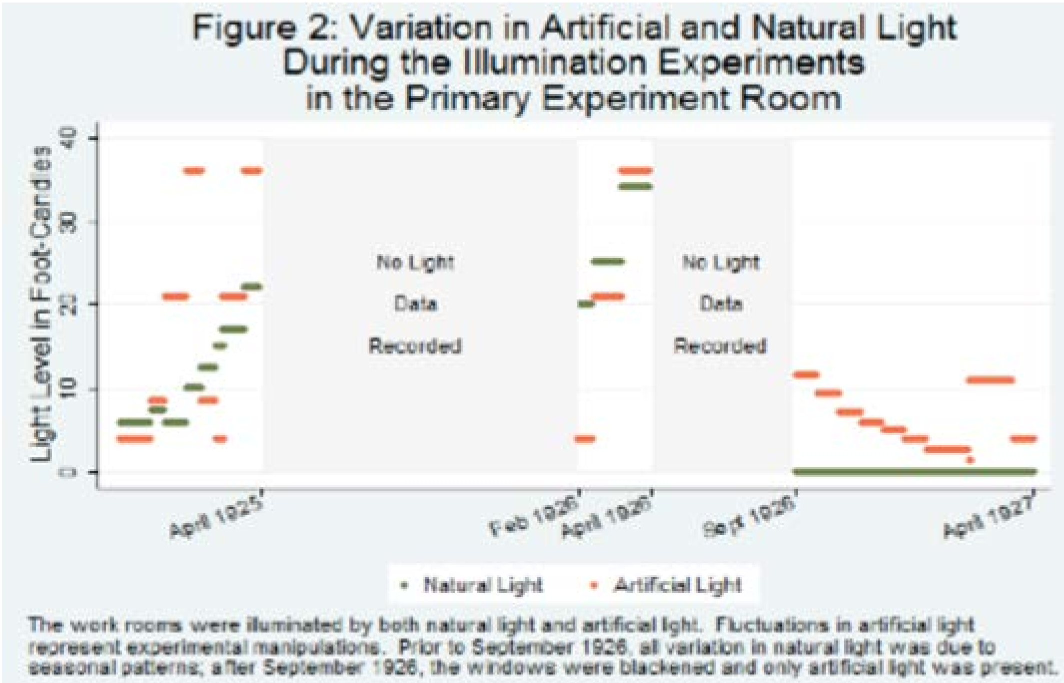

Figure 11. Variation in Artificial and Natural Light during the Illumination Experiments (from Levitt, 2009)

The Hawthrone Experiment correlates changes in lighting with increased productivity as seen in the above figures. Brighter lighting can help with seasonal affective disorder and other health issues. But the experiment did not have a good control group and the higher output during experimentation was due to high supervisor/employee interactions rather than a change in lighting, especially since the output did not change during the low light experiment (Levitt, 2009). Still brighter light does reduce eyestrain with working on a high intensity activity such as engine maintenance and other detailed delicate work. Depending on where the light is located and what the purpose of the light is, different levels of brightness are needed, in any case. The workspace needs bright lights, the bunk light, not so much. And the bridge lights must be capable of dimming to nothing for night operations. Getting the light is important because optimal lighting improves productivity. Underlight a task and its bad. Overlight a task and that’s bad too, as strain can be introduced.

2. USB

The other issue for morale is the new edition of the USB port in the bunk lights. Most sailors today carry at least one USB capable device. Between the two authors of this thesis, we have over 20 plus USB capable items that can charge from a USB port. Some things that make this highly desirable onboard ships; the restriction of USB capable items plugging into the Navy NMCI computers and there is no shock hazard with a USB plug unlike the traditional plug that onboard ship is required to be checked by the electricians before use.

The Sailor would like this implemented even in the legacy lighting. As this provides convenience for charging devices, helps keeps devices ready to use and is good for morale. For example, using a USB device during the cleaning hours on the ship, there is a visible difference in the sailor's morale.

3. Electric Shock

Electrical Shock cases for changing light bulbs are very rare but they still happen often enough for the Experts write articles about in the safety section of the magazine 'Sea Compass'. 65 reported shocks happen in 2010 and one death report in the USCG the same year due to fluorescent light starter and ballast (Burke, 2012). Mostly the ballast tends to degrade and there have been many recalls on the ballasts installed on ships. Our analysis is based on work missed rather than health care cost because the health care cost information is not available. The average hourly rate for a maintenance man is currently $29.34. We assume an electrical shock will take a person out of work for a day or two depending on the severity of the shock. A maintenance work day is 8 hours. So 65 personnel missing 8 to 16 hours at a rate of $29.34 equals a range of $15,256.80 to $30,513.60 cost for the year across the Navy fleet. Also 65 personnel multiplied by the annual rate conversion of 0.00055 equals 3.57%. 3.57% of the full-time equivalent will shock themselves in a year.

4. Headaches

Working with a headache makes concentrating on the job hard. Fluorescents have been known to cause headaches (Freymiller, 2009; Boyce, 2003). Figure 12 shows the week occurrence of headaches cause by the magnetic control gears.

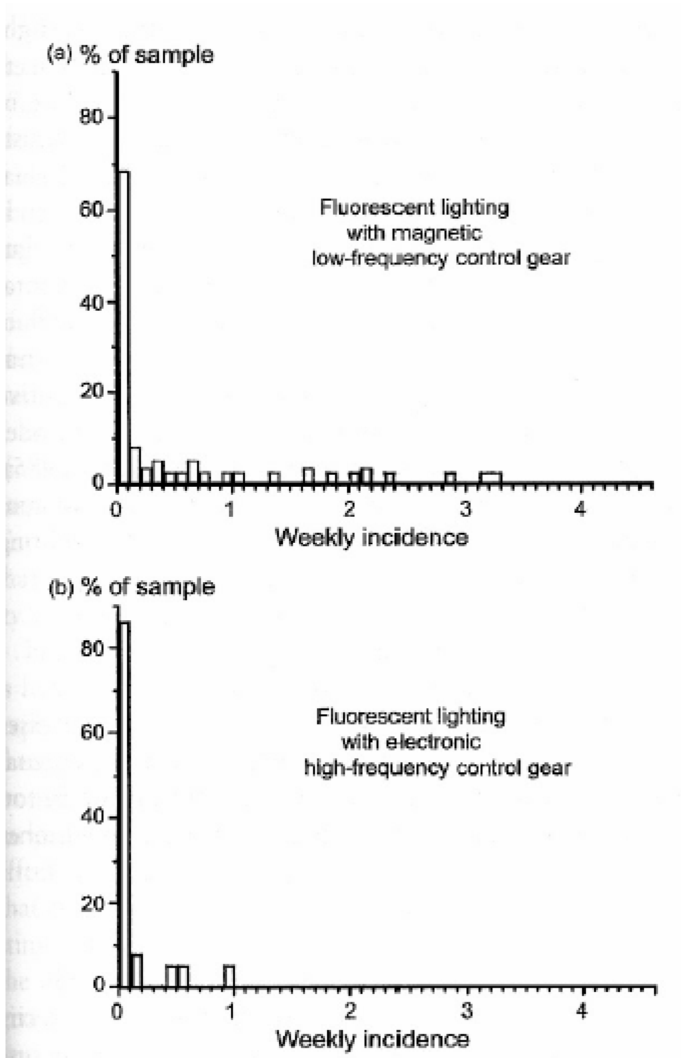

Figure 12. Lighting Ballasts relating to headaches (from Human Factors in Lighting Freymiller, 2009, from Boyce, 2003)

LEDs have no known cause of headaches due to flicker and the electronic magnetic control gears or the ballast types, mostly because it does not have ballasts. As

the fixture parts wear out in the fluorescent lights the reoccurrence of dimming and flickering can reoccur.

There should be further research conducted on how a headache affects the loss of productivity on ships. There have been no quantifiable figures or studies that have analyzed the effects of headaches on productivity caused by CFL lighting.

F. HEALTH

It is known that health complications result from fluorescent lights. The health effects of LED lighting are not known as LEDs have not been adopted on a large scale for long enough to find out all the long term health hazards they may pose. Therefore, here we will focus on what is known about CFL's.

1. Squamous Cell Carcinoma

Squamous Cell Carcinoma (SCC) is the most common form of skin cancer and the 11th most common cancer in the U.S. (Lytle CD1, 1992-1993; Group, 2005; Cronin, 2008). SCC is caused by the UV radiation in natural sunlight and in fluorescent lights. On average a patient costs $20,876 per treatment event. According to the study done on SCC caused by fluorescent lights people in the U.S. have a 3.9% chance of developing SCC. This assumes lifetime exposure of 56 years, 16 years schooling at 1200 hours a week and 40 years working at 2000 hours a week, to total 99,200 hours (Walls, 2011). Using a ratio between the total lifetime exposure over the percentage in the U.S. and the total Navy hours, the percentage for the Navy is 3.44%.

For an example of what the hours mean, the same study also states that 12 hours indoors under fluorescent lighting equals 12 seconds spent outside in Washington, D.C. in July. Using this comparison the total exposure for Navy personnel is 182.5 sun hours outside in Washington, DC.

To put this into a quantifiable cost, we take the total current number of Navy personnel 317,237 (How many active personnel does the US Military Branch Navy have?, 2014) and multiply it by the 3.44% to get 10,912. This 10,912 has a chance to develop SCC due to fluorescent lights. Multiply 10,912 personnel by the average cost

per patient treatment event $20,876 generates a total average cost of $227,798,912. Taking the total number of fixtures throughout the Navy fleet of 434,517 and dividing it by the cost of treating SCC has a per fixture cost of $524.26.

SCC is the worst case out of all the health concerns caused by fluorescent lights.

2. Eye Disease; Cataracts and Pterygia

This comparison came out of an Australian study conducted in 2008-2010. (Walls, 2011) Ratios between the Australian study and the number of Navy personnel were calculated. This study was conducted to find out the percentage of cataracts and Pterygia caused from CFLs.

Australia has a 6.5 million population over the age of 49 and 5.1 million over the age of 55. The 49 age group is the group more susceptible to cataracts and the 55 age group to Pterygia. (Walls, 2011) Using a ratio of 6.5 million over 325,000 cataracts a year to the Navy's number of retirees of 150,000 (625 retire a month times 12 months times 20 years), we get 7,500 cataracts a year for the Navy.

Using a ratio of 5.1 million over 2.14 million cases of Pterygia a year to the Navy's 150,000 retirees produces 49,385 cases of Pterygia per year for the Navy.

Cataracts cost about $3,000 per eye (Cataract Surgery Cost, 1997-2014) and Pterygia $2,000 per eye (Pterygium surgical treatments and cost - Growth on the eye). Multiply the number of cataracts 7,500 by the price doubled $6,000 equals $45,000,000. For Pterygia, multiply the number of cases 49,385 by the price doubled $2,000 equals $197,540,000.

Taking the total number of fixtures throughout the Navy fleet of 434,517 and dividing it by the cost of treating cataracts and Pterygia. This will provide a cost per fixture at $103.56 and $454.62 respectively.

3. Mercury Poisoning

Mercury poisoning is another highly dangerous and possible fatal possibility with fluorescent lights. T-12 contain 21 mg of mercury per bulb enclosed in a 6x6 m^2 room

which is over 35 times high that the lower exposure limit of .1 mg per m^2 prescribed by the safety board. (Poulin & Gibb, 2008). Generally, however, unless a bulb is broken right in someone's face the hazard dissipates itself within minutes if the space is properly ventilated. The problem is when there is no ventilation or a box is dropped and broken, even outdoors, personnel involved need to be checked for mercury poisoning. Methyl mercury (scientific name for mercury) causes many various health aliments from renal, cardiovascular, skin to respiratory. The cost is said to reach $2.9 million worldwide in respiratory infection (Poulin & Gibb, 2008; Bose-O'Reilly, 2010) and $3.7 billion in the drop of I.Q. in children worldwide. Table 14 shows just how much mercury is onboard all ship types and the amount exposed if the ship enters a hypothetical battle and 10% of the fluorescent bulbs break.

Mercury Table				
Ship Class	Number of fixture per ship type	Ship is attacked 10% bulbs	Amount of Mercury released (mg)	Total Mercury on ship
FFG	384	38	806	8,064
CG	881	88	1,850	18,501
MCM	153	15	321	3,213
PC	35	4	74	735
LCS	502	50	1,054	10,542
LPD	3,335	334	7,004	70,035
DDG	1,573	157	3,303	33,033
LCC/Tend	3,317	332	6,966	69,657
LSD	2,919	292	6,130	61,299
LHA/LHD	7,015	702	14,732	147,315
SSN	696	70	1,462	14,616
SSBN	1,864	186	3,914	39,144
CVN	9,555	956	20,066	200,655

Table 14. Mercury amounts per ship type

G. COST COMPARISON OF CFL AND LED'S AT 50,000 HOURS UTILIZING ALL QUANTIFIED TANGIBLES AND SUSPECTED INTANGIBLES

Certain tangibles and suspected intangibles have been defined and calculated, throughout this section. Table 15 through 18 compares all the costs due to the Status Quo of CFLs over installing LEDs. The direct labor hours are based off of 2 sailors changing a light bulb. Therefore, for a .5 direct labor hours, this assumes 2 sailors are employed during this time. The first table illustrates the initial perception of only using

maintenance and disposal cost. The other tables add cost based on different variables and perceptions, such as overhead, operating costs and finally adding in productivity and health care.

We compare the cost of 1 DDG, 1 CVN and the fleet as a whole against the lifecycle of an LED bulb of 50,000 hours. After obtaining a cost comparison, we also identified the break-even direct labor hour and FTE for the first 2 tables by adjusting the direct-labor hours using the goal-seek function in excel. The break-even for the direct labor hour provides a basis for the average time to change a light bulb that would make implementing LED lights beneficial.

Table 15 shows the baseline cost of the maintenance person plus disposal costs given the four different labor hours. The CVN and the Navy Fleet has a payback period of less than 5 years when using 1.42 direct labor hours. The DDG has a payback period of less than 5 years when using 4 direct labor hours.

The break-even for direct-labor hours on 1 DDG is 1.4228 hours. Therefore, if on average the direct labor took less than 1.4228 hours to change a T12 light bulb, while only taking direct labor and disposal costs into consideration, implementing LED lights on a DDG would be beneficial. On a CVN, the break-even direct labor is 1.03 hours and for the Navy wide is 1.072 hours. Converting the break-even direct-labor hours of a DDG and CVN to a FTE sailor equates 4.85 and 29.36 FTE sailors respectively.

Using Table 15, we calculated the break-even direct labor hours Navy-wide and figured the break-even FTE sailor. There are 1,268.23 FTE sailors required to change only T12 light bulbs on across the Navy fleet at a rate of 1.07 direct labor hours to achieve the break-even point.

summary of basecase

	CFL (50,000 Hrs basis)			Whole LED lifecycle (50,000 Hrs)			Savings from LED vs CFL		
Direct Labor Hours	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide
0.5	398,871.80	3,336,221.87	148,309,036.34	1,132,560.00	6,879,600.00	311,368,410.00	(733,688.20)	(3,543,378.13)	(163,059,373.66)
0.75	597,630.27	4,998,666.66	219,630,998.22	1,132,560.00	6,879,600.00	311,368,410.00	(534,929.73)	(1,880,933.34)	(91,737,411.78)
1.42	1,130,302.97	9,454,018.72	410,774,360.76	1,132,560.00	6,879,600.00	311,368,410.00	(2,257.03)	2,574,418.72	99,405,950.76
4.00	3,181,490.39	26,610,449.02	1,146,818,950.83	1,132,560.00	6,879,600.00	311,368,410.00	2,048,930.39	19,730,849.02	835,450,540.83

*All hours based on 2 person job; therefore basis is for .5 hrs with 2 people perfoming task + disposal cost
** 5 year is discounted by 2.7%
*** Green highlighted saving shows when installing LED benefits vs CFL bulbs

Table 15. Summary of baseline maintenance and disposal costs

Table 16 adds all the fully burdened maintenance overhead. We added the cost of the supply department, supervisors, tools, and training. As shown below, all categories have a payback period of less than 5 years when assuming 1.42 direct labor hours. The break-even point for direct-labor hours to be beneficial on 1 DDG is 1.06 hours. The break-even point on a CVN is .081 direct labor hours.

Base + Fully Burden maintenance overhead

	CFL (50,000 Hrs basis)			Whole LED lifecycle (50,000 Hrs)			Savings from LED Vs CFL over 5.7 year basis		
Direct Labor Hours	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide
0.5	549,459.77	4,315,416.93	193,752,480.35	1,132,560.00	6,879,600.00	311,368,410.00	(583,100.23)	(2,564,183.07)	(117,615,929.65)
0.75	770,633.84	6,390,277.85	276,049,624.67	1,132,560.00	6,879,600.00	311,368,410.00	(361,926.16)	(489,322.15)	(35,318,785.33)
1.42	1,435,450.96	11,950,905.11	514,972,522.03	1,132,560.00	6,879,600.00	311,368,410.00	302,890.96	5,071,305.11	203,604,112.03
4	3,995,493.02	33,363,469.77	1,435,003,977.53	1,132,560.00	6,879,600.00	311,368,410.00	2,862,933.02	26,483,869.77	1,123,635,567.53

*All hours based on 2 person job; therefore basis is for .5 hrs with 2 people perfoming task
** 5 year is discounted by 2.7%
*** Green highlighted saving shows when installing LED benefits vs CFL bulbs
**** LED lifecycle is installation cost

Table 16. Summary with fully burden maintenance overhead added

Table 17 illustrates the cost of changing a T12 bulb summing the maintenance person, fully burdened maintenance overhead and operating cost. All categories are beneficial considering 1.42 direct labor hours. If assuming the average time to change a light bulb is .5 or .75 direct labor hours then only the DDG and Navy-wide will prove beneficial.

Base + Fully Burden maintenance overhead + Operating Cost (Fuel Consumption + Shore Power)									
	CFL (50,000 Hrs basis)			Whole LED lifecycle (50,000 Hrs)			Savings from LED Vs CFL over 5.7 year basis		
Direct Labor Hours	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide
0.5	1,248,201.19	4,315,416.93	386,769,019.37	1,132,560.00	6,879,600.00	311,368,410.00	115,641.19	(2,564,183.07)	75,400,609.37
0.75	1,469,375.26	6,390,277.85	469,066,163.69	1,132,560.00	6,879,600.00	311,368,410.00	336,815.26	(489,322.15)	157,697,753.69
1.42	2,134,192.38	11,950,905.11	707,989,061.05	1,132,560.00	6,879,600.00	311,368,410.00	1,001,632.38	5,071,305.11	396,620,651.05
4	4,694,234.44	33,363,469.77	1,628,020,516.55	1,132,560.00	6,879,600.00	311,368,410.00	3,561,674.44	26,483,869.77	1,316,652,106.55

*All hours based on 2 person job; therefore basis is for .5 hrs with 2 people perfoming task
** 5 year is discounted by 2.7%
*** Green highlighted saving shows when installing LED benefits vs CFL bulbs
**** LED lifecycle is installation cost

Table 17. Summary of baseline with fully-burdened maintenance overhead and operating cost

Finally, the productivity loss and health care cost are added in Table 18. The electric shock was the only productivity variables quantified. The productivity was only added to the Navy-wide calculation. The health care costs were added to all categories per fixture for SCC, cataracts, and Pterygia. When all cost is included, the total saving for implementing LED bulbs is extensive.

Base + Fully Burden maintenance overhead + Fuel Consumption + Shore Power + Productivity loss + Medical Cost									
	CFL (50,000 Hrs basis)			Whole LED lifecycle (50,000 Hrs)			Savings from LED Vs CFL over 5.7 year basis		
Direct Labor Hours	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide	1 DDG	1 CVN	Navy-wide
0.5	9,325,569.46	53,380,422.52	2,618,089,856.51	1,132,560.00	6,879,600.00	311,368,410.00	8,193,009.46	46,500,822.52	2,306,721,446.51
0.75	9,546,743.53	55,455,283.44	2,700,387,000.83	1,132,560.00	6,879,600.00	311,368,410.00	8,414,183.53	48,575,683.44	2,389,018,590.83
1.42	10,211,560.65	61,015,910.70	2,939,309,898.19	1,132,560.00	6,879,600.00	311,368,410.00	9,079,000.65	54,136,310.70	2,627,941,488.19
4	12,771,602.71	82,428,475.37	3,859,341,353.68	1,132,560.00	6,879,600.00	311,368,410.00	11,639,042.71	75,548,875.37	3,547,972,943.68

*All hours based on 2 person job; therefore basis is for .5 hrs with 2 people perfoming task
** 5 year is discounted by 2.7%
*** Green highlighted saving shows when installing LED benefits vs CFL bulbs
**** LED lifecycle is installation cost
***** Assume Electric shock person misses conservative 8 hours of work
******Medical cost = # Fixtures * $1082.44 ; Fixtures: Navy fleet- 434,517, DDG-1,573, CVN-9,555
--- SCC = 524.26 ; Cataracts = 103.56; Pteryggi = 454.62

Table 18. Summary of baseline with fully-burdened maintenance overhead, operating cost, productivity loss and medical cost

VI. CONCLUSION

The values of each stakeholder within an adoption chain for a new technology must be aligned in order for technology adoption to be successful. The LED lights adoption chain appears to have a few kinks. One appears that the barrier for entry is large based on the MILSPEC specifications for an item that is low volume by industry standards. A further issue is that all the stakeholders value a reduction in fuel and energy savings, however, there are other programs that require less up-front funding and produce a faster rate of return by saving copious amount of fuel, such as installing stern-flaps on DDGs. The stakeholders understandably (e.g., NAVSEA/PEO DDGs) will prioritize items that are perceived to be most valuable and feasible to them.

The key issue for LEDs is the lack of perception and analysis into the second and third order consequences of adopting LEDs. Additional analysis can determine where the fully added value comes from and what it amounts to. The greatest return on investment in implementing LED lights is in the maintenance hours saved, not the energy saving, as identified in the DDG-51 Class SSL Initiative (Griggel, 2011, p. 176). Energy and fuel savings are how the current priorities are evaluated by N45E when considering funding for such programs like LED lighting. Since N45E controls' funding for such programs this is a major hindrance to LED adoption.

Quantifying the intangibles provides a clearer picture on what is really being saved by adopting LED lighting on vessels. Really, what is more hazardous that breaking a gaseous hazard in a confined space, such as a submarine? What is the value of limited space and health care concerns? The obvious value of the limited energy savings is not going to be the final selling point for LED lighting and we believe these values will not be the eventual drivers for LED adoption. Instead, quality of life, sailor health and safety, space concerns and the higher value alternative uses of manpower are the key issues in LED adoption

As illustrated in Tables 15 through 18 we have shown how looking at the non-obvious answer can drastically change the break-even point. If the direct labor hours are

the only factor taken into consideration, then break-even point for LED lighting, Navy-wide, is approximately one hour to change the lamp. Of note, this Navy-wide breakeven is very significantly lower than the SME estimate of four hours, which gives the Navy significant room for error in this estimate while still being assured that the payback on LED adoption across the fleet is positive. As other factors are added, such as maintenance overhead, productivity and potential medical costs the payback period significantly reduces in all categories. From a financial standpoint the perception of value on adopting LEDs should be prioritized using all stakeholders values verses only the energy-saving potential.

Another perception taken into consideration is the end-users value on sailors' time. Aligning the end-user with the rest of the adoption chain is important to find the total value of any particular project. As ships' managers of adopting new technology, should we place a burden of five FTE sailors on a DDG a year to change one specific type of light bulb? Should the Navy employ over 1,200 FTE sailors to change only T12 light bulbs each year across the Navy's 241 ships considered? There are many different ways to value implementing LED lights and the perception of the break-even points matters to all stakeholders. The capability and sustainability of the Navy's fleet is imperative and the sailors should not be burdened with the changing light bulbs unnecessarily. We suggest that in this age of reduced manning and increase of requirements placed on the sailors, the potential impact of LED lighting on sailor's use of time ought to be a key value considered.

LIST OF REFERENCES

3M TOC of Lights. (2013). Unpublished PowerPoint presentation used by 3M and Lockheed Martin.

Adner, R. (2012). *The wide lens: A new strategy for innovation.* New York: Penguin Group.

Allison, G., & Zelikow, P. (1999). *Essence of decision: Explaining the Cuban Missile Crisis.* New York: Longman.

Association for Facilities Engineering. (2008, January 3). *The advantages of group relamping: Ideas that build business.* Retrieved from www.afestlouis.org/Download/Relamp.ppt

Bose-O'Reilly, M. M. (2010, Sept.). *Mercury exposure and children's health*. Retrieved from National Library of Medicine with the National Institutes for Health website: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3096006/

Bowers, P., Goering, J., & Leiderman, D. (2012). *Analyzing lifecycle lighting costs on hospital ship USNS Comfort (T-AH 20)* (Unpublished master's thesis). Naval Postgraduate School, Monterey, CA.

Boyce, P.R. (2003). *Human factors in lighting*. New York: Taylor and Francis.

Burke, E. (2012). Ask the experts: How many sailors does it take to change a light starter? *Sea Compass*, pp. 8–9.

Cizek, C. J. (2009). *Shipboard LED lighting a business case analysis* (Master's thesis, Naval Postgraduate School). Retrieved from http://edocs.nps.edu/npspubs/scholarly/theses/2009/Dec/09Dec_Cizek.pdf

Cronin, B. L. (2008, Oct 9). *Cost of treatment for squamous cell carcinoma of the head and neck in the United States*. Retrieved from Wiley Online Library: http://onlinelibrary.wiley.com/doi/10.1046/j.1524-4733.2001.40202-73.x/abstract

DASN M&B. (2012, October 11). *ASN (RDA) Organization structure*. Retrieved from Department of the Navy Research, Development & Acquisition: http://acquisition.navy.mil/rda/home/organizations/asn_rda

Defense Logistics Agency Energy. (2014, May 5). *DLA energy standard prices.* Retrieved from http://www.energy.dla.mil/dla_finance_energy/documents/fy14_oct_01_2013_standard_prices_v3.pdf

Defense Logistics Agency Enterprise Business Solutions. (2014, May 15). *DLA Internet bid board system awards.* Retrieved from https://www.dibbs.bsm.dla.mil/Awards/AwdRecs.aspx

Defense Logistics Agency Transaction Services. (2014, May 15). *DAASC inquiry system (DAASINQ).* Retrieved https://www.transactionservices.dla.mil/daasinq/daasinq_niin.asp

Department of the Navy. (2014, April 23). *The Navy Fact File*. Retrieved from http://www.navy.mil/navydata/nav_legacy.asp?id=146

Deputy Director, Office of the Under Secretary of Defense (Comptroller). (2014). *FY 2015 Department of Defense (DoD) military personnel composite standard & reimbursement rates.* [Memorandum]. Washington, DC: Office of the Under Secretary of Defense. Retrieved from http://comptroller.defense.gov/FinancialManagement/Reports/rates2015.aspx

DocShop. (n.d.). *Cataract surgery cost (1997-2014)*. Retrieved from http://www.docshop.com/education/vision/eye-diseases/cataracts/cost

Energy Focus. (2013, August 22). Energy Focus, Inc. under contract to develop an “all platform” LED lighting system for new Navy ships. Retrieved from http://www.energyfocusinc.com/energy-focus-inc-under-contract-to-develop-an-all-platform-led-lighting-system-for-new-navy-ships/

Energy Focus. (2013, November 4). *Energy Focus military lighting products.* Retrieved from http://www.energyfocusinc.com/wp-content/uploads/MilitaryShips.pdf

Energy Focus. (2013, July 3). *Energy Focus: Specifications: IntelliTube LED replacement lamp, 24”, T12 LED lamp.* Retrieved from http://www.energyfocusinc.com/wp-content/uploads/LED_IntelliTubeM1.pdf

Energy Focus. (2011). *LED/IntelliTube NAVSEA: LED Fluorescent tube replacement*. Retrieved from http://www.energyfocusinc.com/led-technology/projects/led-intellitube/

Exec. Order No. 13,514, *printed in Federal Register in Energy: Regulation and conservation, federal leadership efforts; Environment: Sustainability and conservation, federal leadership efforts (2009)*

Farmer, J. (2011, October 6). *Solid state ship lighting system evaluation.* Retrieved from http://www.nsrp.org/6-Presentations/Joint/100411_Solid-State_Ship_Lighting_System_Evaluation_Farmer.pdf

FindTheBest.com, Inc. (2014). *How many active personnel does the US Military Branch Navy have?* Retrieved from http://us-military-branches.findthebest.com/q/2/2405/How-many-active-personnel-does-the-US-Military-Branch-Navy-have

Freymiller, A. T. (2009). *LED shipboard lighting a comparative analysis* (Master's thesis, Naval Postgraduate School). Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a514251.pdf

Gourley, S. R. (2013, Oct 15). *Advancements provide alternative energy and power*. Retrieved from https://www.google.com/search?q=DARPA+Advancements+provide+alternative+energy+and+power&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a

Griggel, R. (2011). *DDG-51 Class solid state lighting initiative fore reduced maintenance.* NSWCCD CODE 916.

Group, I. W. (2005, Jun 7-29). *World Health Organization International Agency for Research on Cancer."Exposure ot Artificial UV Radiation and Skin Cancer"*. Retrieved from http://www.iarc.fr/en/publications/pdfs-online/wrk/wrk1/ArtificialUVRad&SkinCancer.pdf

Icon Lasik. (n.d.). *Pterygium surgical treatments and cost - Growth on the eye*. Retrieved from http://iconlasik.com/pterygium

Kingsley, L. C., Fike, B. A., Reubelt, V. A., & Amerson, T. L. (2012). *Cutter energy efficient lightig: Cost study report.* Washington, DC: U.S. Department of Homeland Security.

L.C. Doane Company. (n.d.). Document name. Retrieved from http://www.lcdoane.com/

Light-Pod. (2008). *Light-Pod Military Compliant LED Lighting Fixture*. Retrieved from http://www.light-pod.com/about2.htm

Lytle CD1, C. W. (1992-1993, December). *An estimation of squamous cell carcinoma risk from ultraviolet radiation emitted by fluorescent lamps*. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1343229

MarineLink.com. (2013, August 22). *Energy Focus to develop Navy LED lighting*. Retrieved from http://www.marinelink.com/news/lighting-develop-energy357922.aspx

Markey, E., & Hatch, B. (2010, October 12). *Request for information solid state light.* Retrieved from https://www.fbo.gov/index?s=opportunity&mode=form&id=4adfef27affa4d124a391cef72f1c6ec&tab=core&_cview=0

McCoy, Monica. (2012). *NAVSEA reducing fleet energy consumption*. Retrieved from http://greenfleet.dodlive.mil/files/2012/01/NAVSEA-Shipboard-Efficiencies-Currents-Summer-12.pdf

Naval Center for Cost Analysis. (2014, February). *Joint Inflation Calculator.* Retrieved from https://www.ncca.navy.mil/tools/inflation.cfm

Naval Seas Systems Command. (2014). *About NAVSEA.* Retrieved from: http://www.navsea.navy.mil/AboutNAVSEA.aspx

NAVSEA-Naval Surface Warfare Center. (2014). *Ship Systems Engineering Station*. Retrieved from http://www.navsea.navy.mil/nswc/Centers/Philadelphia.aspx

NAVSEA Organization. (2011, Aug). *NAVSEA corporate leadership.* Retrieved from http://www.navsea.navy.mil/Organization/HQ.aspx

Office of Naval Research (n.d.). *ONR Organization.* Retrieved from www.onr.navy.mil/science-technology

Office of Naval Research: Science & Technology. (n.d). *Solid-State Lighting for Submarines.* Retrieved from http://www.onr.navy.mil/Media-Center/Fact-Sheets/Solid-State-Lighting-Submarines.aspx

Ottman, D. E. (2012). *ONR's Techsolutions lights up the ship with green technology.* Retrieved from www.onr.navy.mil/innovate

Ottman, D. E. (2011, March 1). *ONR'S TechSolutions creating green ideas that light up ships and submarines*. Retrieved from http://www.onr.navy.mil/Media-Center/Press-Releases/2011/Solid-State-SSL-Techsolutions.aspx

Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility Public Affairs. (Dec 2011). *NAVSEA Newswire DEC08-02: USS Chaffe (DDG 90) first ship to receive complete LED lighting upgrade*. Retrieved from http://www.navsea.navy.mil/Newswire2011/08DEC11-02.aspx

Poulin, J., & Gibb, H. (2008). *Mercury: Assessing the environmental burden of disease at national*. Retrieved from http://whqlibdoc.who.int/publications/2008/9789241596572_eng.pdf

Rachel S. Klein, R. M. (2009, Feb). *The risk of ultraviolet radiation exposure from indoor lamps in lupus erythematosus.* Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2829662/

SCRA. (2014). *NSRP executive control board selects r&d project portfolio*. Retrieved from www.nsrp.org/7-Press_Release-RA1101.html

Shelter Lighting System [SLS]. (2012). Unpublished presentation used by TechShot.

Steven D. Levitt, J. A. (2009, May). *Was there really a hawthorne effect at the Hawthorne plant? An analysis of the original illumination experiments*. Retrieved from https://www.msu.edu/~conlinmi/teaching/PIM821/levitthawthorne.pdf

Stewart, K. A. (2013, September 5). *NPS student analysis reveals multi-million dollar savings for USNS Comfort*. Retrieved from www.nps.edu/about/news/NPS-Student-Analysis-Reveals-Multi-Million-Dollar-Savings-for-USNS-Comfort.html

U.S. Department of the Navy Energy Security. (n.d.). *Green fleet solid state lighting* [Fact sheet]. Retrieved from http://greenfleet.dodlive.mil/files/2012/06/20120620-Solid-State-Lighting-FactSheet.pdf

U.S. Department of the Navy Energy Security. (n.d.). *Green fleet stern flaps* [Fact sheet]. Retrieved from http://greenfleet.dodlive.mil/files/2012/06/20120620-Stern-Flaps-FactSheet.pdf

Vigliotti, A., & Hatch, B. (2011). *SSL cost calculator112811*. Unpublished datasheet used by NAVSEA 05.

Walls, P. M. (2011, Dec). *Eye disease resulting from increased use of fluorescent lighting as a climate change mitigation strategy*. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222423/

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A: A SIMPLE QUESTION

Simple Answer to a Simple Question:

Consider you are asked a simple question, "how long did it take you to change the light bulb out in your garage and what did it cost?" Your answer may be, "well only 3 minutes and about $8.75 for this brand new LED light". This is a very plausible answer to a simple question. However, there is a miniscule lack of depth in both the question and answers. Both perceptions are considering the direct tangibles that are obvious and leaving out very tangible perceptions of the story.

The simplicity of the answer must be expanded to figure the real cost of changing a light bulb. Consider in this scenario that the light bulb was purchased from any store. The time it takes to purchase a bulb, and only a bulb, is approximately 35 minutes. The 35 minutes includes the 15 minute drive to the local store about 5 miles away, then 5 minutes to find and purchase a bulb, then 15 minutes to drive back. Once back home allow 5 minutes to locate a screwdriver and step stool. These tools are necessary to unscrew the beautiful cover that is approximately 12 feet off the floor. Add 3 minutes, that answered the initial question, to actually unscrew the cover, unscrew the bulb, put the bulb down, screw the new bulb into the socket and screw the cover back on (this is considering the expertise of the individual changing the bulb). Add another 3 minutes to place the used light bulb in a storage compartment to be discarded properly as hazardous material, put the screwdriver away and put the step-stool back into the closet. 2 minutes were reduced for cleanup since the tools have been found previously.

The actual cost for changing a light bulb in your garage, is now 46 minutes * $24.5/hr + $8.75 = $27.53. The opportunity cost for doing something else increases the cost approximately $18.78. This is only in time alone, not including the storage space that the new hazardous material is now taking up in your closet.

In the Navy, the supplier on a ship is also paid for by the Navy and should be considered in the chain when considered for labor. The supply personnel is placing

hands on the item as well as ordering, purchasing, tracking and physically stocking these products.

APPENDIX B. TRANS-LEDGER REPORT

USS CARL VINSON (CVN 70) provided a trans-ledger report for NIIN 001522996 from Jan 2013 thru Jan 2014. This data provides an estimate of how many T12, Fluorescent, light bulbs were issued, requisitioned and received. The price for all but one transaction was $32.25 a box. Each box contains 30 bulbs. The unit of issue is a box that measures 24x8x10 inches. 42 boxes were onboard which took up a space approximately 60x68x25 inches.

Actual Transledger Report from CVN 70 - Fluorescent T12 Bulbs

Date	Issued	RQN	RCV'd	Price for Transaction	-	Date (cont)	Issued (cont)	RQN (cont)	RCV'd (cont)	Price for Transaction(cont)
1/24/2014		8		$ 319.84		9/18/2013			8	$ 2,558.72
1/23/2014	2.00			$ (79.96)		9/11/2013		8		$ 2,558.72
1/21/2014	2.00			$ (79.96)		8/27/2013	3.00			$ (959.52)
1/20/2014	4.00			$ (159.92)		8/26/2013	3.00			$ (959.52)
1/19/2014		8		$ 319.84		8/26/2013	2.00			$ (639.68)
1/18/2014	5.00			$ (199.90)		8/23/2013		8		$ 2,558.72
1/17/2014	3.00			$ (119.94)		8/21/2013	3.00			$ (959.52)
1/16/2014		12		$ 479.76		8/6/2013	5.00			$ (1,599.20)
1/16/2014	3.00			$ (119.94)		8/2/2013			4	$ 1,279.36
1/14/2014	1.00			$ (39.98)		7/23/2013			1	$ 319.84
1/14/2014	2.00			$ (79.96)		7/19/2013	2.00	4		$ 639.68
1/13/2014	3.00			$ (119.94)		7/19/2013	2.00			$ (639.68)
1/9/2014	3.00			$ (119.94)		7/12/2013	2.00			$ (639.68)
12/30/2013			4	$ 159.92		7/11/2013		1		$ 319.84
12/19/2013			43	$ 1,719.14		6/25/2013	1.00			$ (319.84)
12/12/2013		4		$ 159.92		6/24/2013			48	$ 15,352.32
12/11/2013	1.00			$ (39.98)		6/10/2013		48		$ 15,352.32
12/11/2013	1.00			$ (39.98)		4/2/2013	1.00			$ (319.84)
12/9/2013	2.00			$ (79.96)		4/2/2013	1.00			$ (319.84)
12/8/2013		43		$ 1,719.14		4/1/2013	4.00			$ (1,279.36)
12/6/2013	2.00			$ (79.96)		4/1/2013	4.00			$ (1,279.36)
12/6/2013	4.00			$ (159.92)		3/22/2013	3.00			$ (959.52)
11/22/2013	1.00			$ (39.98)		3/21/2013	4.00			$ (1,279.36)
11/14/2013	10.00			$ (399.80)		3/21/2013	1.00			$ (319.84)
11/14/2013	10.00			$ (399.80)		3/18/2013	2.00			$ (639.68)
11/13/2013	1.00			$ (39.98)		3/15/2013	2.00			$ (639.68)
11/6/2013	3.00			$ (119.94)		3/15/2013	4.00			$ (1,279.36)
10/28/2013	6.00			$ (239.88)		3/11/2013	3.00			$ (959.52)
10/9/2013			8	$ 319.84		1/11/2013	1.00			$ (319.84)
9/27/2013	3.00			$ (119.94)		1/11/2013	1.00			$ (319.84)
9/25/2013	3.00			$ (119.94)		1/2/2013	1.00			$ (319.84)
Total boxes	130.00	144.00	116.00							
Total Price	$(4,192.50)	$4,644.00	$4,073.39							
		Price/box			Price/Bulb					
30	bulbs/box	$ 32.25	$ 39.98		$ 1.08	$ 1.33				

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C. LIGHT FIXTURE CALCULATIONS

Expanding on APPENDIX B: Shipboard Fixture Count Calculations (Cizek, 2009), we added the expected to change a light bulb. The figures for the number of light fixtures are for T12 fixtures. This creates another uncertainty of how many actual light bulbs are on a ship. There are three types of T12 fixtures, symbols 77.4, 331.1 and 333.1. These fixtures have two, one and three bulbs, respectively. Therefore, it is difficult to determine the specific number of bulbs. For simplicity, we multiplied the number of fixtures times two. This gave us an estimated number of light bulbs on a ship class.

T12 bulbs do vary in time life expectancy and claim to last approximately 1 - 1.2 years. Industry experts are expecting this to decrease to 6-8 months. This is due to the fact that CFL T12 bulbs are becoming obsolete. The bulb will be obsolete and the quality of the product is going to decrease as the quality of the stock pile is drawn down.

Light Fixture Calculations					Expected Change rate	
Class	Name	Light Displacement	# of Light Fixture	# of Lamps	20%	50%
AUX	Blue Ridge	13038	3317	8193	1638.6	4096.5
	Emory S. Land	13991	3560	8793	1758.6	4396.5
DDG	Arleigh Burke	6691	1573	2856	571.2	1428
SSN	Los Angeles	5700	696	1740	348	870
	Seawolf	7568	924	2310	462	1155
	Virginia	5921	1392	2018	403.6	1009
FFG	Perry	3144	384	960	192	480
CG	Ticonderoga	7218	881	2203	440.6	1101.5
SSBN/SSGN	Ohio	15275	1864	4660	932	2330
MCM	Avenger	1253	153	383	76.6	191.5
LSD	Whidbey Island	11471	2919	7210	1442	3605
	Harpers Ferry	11604	2952	7291	1458.2	3645.5
CVN	Nimitz	78280	9555	23888	4777.6	11944
	Enterprise	75704	9240	23100	4620	11550
LPD	San Antonio	19013	4838	8237	1647.4	4118.5
LHA/LHD	Tarawa	25884	6586	17327	3465.4	8663.5
	Wasp	28050	7137	17327	3465.4	8663.5
LCS	Freedom	2135	502	904	180.8	452
PC	Cyclone	288	35	88	17.6	44

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D. FTE AND COST COMPARISON PER SHIP CLASS

Illustrated on the following pages are the number FTE sailors required to change T12 fluorescent bulb for 1 year. The ships classes are calculated by changing 100 percent of the estimated number of T12 light bulbs. Factors that are considered in quantifying the FTE are direct labor and indirect labor. The indirect labor was measured by summing the total number of hours by the supply personnel, supervisors and training. The number of fixtures and number of lamps vary depending on ship class, so different ship classes are considered on a ship by ship basis. Assumptions for number of light bulbs changed are estimated as well.

Direct-labor hours (DL-HRS) are compared by different amount of time it takes on average to change a T12 fluorescent light bulb. There are four expected DL-HRS expected, .5, .75, 1.42 and 4. The expected time to change a bulb is about .5 hrs. This means, it can take a sailor 5 minutes for some light bulbs or 45 minutes.

The number of FTE supply personnel is based on the number of tasks completed and length of time required to accomplish each task. The supply personnel are dependent upon the number of bulbs changed throughout the year, not the direct labor hours of the maintenance person. The cost of supplying fluorescent bulbs verses LED bulbs is a variable cost and variable full-time person, but is an integral part of changing light bulbs. The occurrence each tasks was performed is from Appendix A, CVN 70's transledger report. The length of time each task takes to perform is estimated. The amount of times the supply personnel dispose of the HAZMAT off the ship is estimated. The spill kits and annual inventory are also estimated. All the hours estimated spent completing all these task summed together multiplied by .00055 provides the number of FTE supply personnel required to support changing the predetermined amount of bulbs.

The number of hours required to supervise a sailor changing a light bulb seems miniscule and unimportant calculating the cost of a light bulb. If a private business study is considered, all factory overhead should be considered to make a complete assessment of a product. The maintenance man's chain of command is not free and either is there

time. In attempting to allocate the cost of supervisors to changing a light bulb, some assumptions had to be made.

Each maintenance person is required to complete their PQS prior to completing any maintenance, this time and training cost should be factored in as well. The 3M PQS's were considered for training, which states an estimated 8 weeks for each. We estimated that 40 hours would be consumed to complete the light bulb portion of the PQS. At minimum an E-5 is required to sign each line item of training, so this time and cost was considered as well. Since all training does require some administrative burden, the chain of command was also estimated and taken into consideration.

Tools are added as a small cost as they are needed to be maintained each year to change light bulbs on a ship. The costs of materials are added for bulbs only, using Appendix B cost per bulb of $1.08.

All these estimated values, both time and money, are added together considering bulbs require two maintenance people to change a light bulb. There is then an actual cost per light bulb that illustrates the total cost divided by the number of bulbs replaced.

A. FTE TO CHANGE 1428 T12 FLUORESCENT BULBS ON A DDG

Direct Labor Hours				
bulbs /yr	2856			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	1428	2142	4055.52	11424
Full-Time Equivalent	0.7854	1.1781	2.230536	6.2832
DL Maintenance Cost	$ 41,897.52	$ 62,846.28	$ 118,988.96	$ 335,180.16
Full-Time Equivalent w/2 performing task	1.5708	2.3562	4.461072	12.5664
DL Maintenance Cost w/2 performing task	$ 83,795.04	$ 125,692.56	$ 237,977.91	$ 670,360.32

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	33.68615385	0.2	6.737230769	$ 197.67
Receive / Store Used Bulbs	33.68615385	0.2	6.737230769	$ 197.67
Disposal off ship	5	2	10	$ 293.40
Disposal price	2856			$ 285.60
Requisitioned	7.323076923	0.2	1.464615385	$ 42.97
Receive New Bulbs	5.126153846	1	5.126153846	$ 150.40
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	50.06523077	
Full-Time Supply Person			0.027535877	
Total Supply Indirect Cost				$ 1,754.51

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	1428	2142	4055.52	11424
Full-Time maintenance/supply person required per year		1.598	2.384	4.489	12.594
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	1.598	2.384	4.489	12.594
LPO (E-6)	0.75	1.199	1.788	3.366	9.445
LCPO (E-7)	0.5	0.799	1.192	2.244	6.297
Dept LCPO (E-8)	0.068	0.109	0.162	0.305	0.856
CMC (E-9)	0.0125	0.020	0.030	0.056	0.157
DIVO 0-1 (ELECTRO)	0.445	0.711	1.061	1.997	5.604
DIVO O-2 (AUXO)	0.445	0.711	1.061	1.997	5.604
Department Head (0-3)	0.045	0.072	0.107	0.202	0.567
XO (0-4)	0.0125	0.020	0.030	0.056	0.157
CO (0-5)	0.0125	0.020	0.030	0.056	0.157
Total Hrs Spent Supervising	3.2905	5.259	7.844	14.770	41.440
Full-Time Supervisors		0.0029	0.004	0.008	0.023
OVHD /yr for Light bulbs		$ 3,746.10	$ 5,586.87	$ 10,520.16	$ 29,517.00

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		1.5708	2.3562	4.461072	12.5664
3M PQS 301	40	62.83	94.25	178.44	502.66
Maintenance Man 3M PQS	40	62.83	94.25	178.44	502.66
DCPO PQS	40	62.83	94.25	178.44	502.66
Electrical Training Annual	1	1.57	2.36	4.46	12.57
HAZMAT	1	1.57	2.36	4.46	12.57
JLG (jack lift) / Harness	1	1.57	2.36	4.46	12.57
Total HRS spent training maintenance man		193.21	289.81	548.71	1545.67
Full-Time Maintenance Person to be trained		0.1062646	0.1593969	0.3017915	0.8501170
3M PQS 302-307 (if supervisor completes concurrently)	50	0.14	0.22	0.41	1.14
16 Supervisors (2	100	0.289262831	0.43140256	0.812337032	2.27921903
Full-Time Supervisors Trained		0.000159	0.000237271	0.000446785	0.00125357
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	23.73248835	35.59842691	67.39914228	189.8556283
Full-Time Trainers		0.013052869	0.019579135	0.037069528	0.104420596
Cost for Maintenance Man Training		$ 5,668.73	$ 8,503.10	$ 16,099.21	$ 45,349.88
Cost for Supervisors Training & Trainers		$ 17,110.14	$ 25,663.22	$ 48,585.46	$ 136,853.22
Cost for Training		$ 22,778.87	$ 34,166.32	$ 64,684.67	$ 182,203.10

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change T12 Fluorescent Light Bulbs on a DDG				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	1428	2142	4055.52	11424
Total DL Cost	$ 83,795.04	$ 125,692.56	$ 237,977.91	$ 670,360.32
Total Indirect Cost	$ 28,944.48	$ 33,669.61	$ 61,525.14	$ 168,789.74
Total Cost for Materials	$ 3,084.48	$ 3,084.48	$ 3,084.48	$ 3,084.48
Total Cost to change CFL bulbs	$ 115,824.00	$ 162,446.65	$ 302,587.53	$ 842,234.54
Actual Cost per light bulb	$ 40.55	$ 56.88	$ 105.95	$ 294.90

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	1428	2142	4055.52	11424
Maintenance	1.5708	2.3562	4.461072	12.5664
Supply	0.027535877	0.027535877	0.027535877	0.027535877
Full-Time trained	0.1194766	0.1792133	0.3393078	0.9557911
Full-Time Person Supervising	0.003	0.004	0.008	0.023
Total Full-Time people	1.720705088	2.567263239	4.836039082	13.57251919

B. FTE TO CHANGE 11,944 T12 FLUORESCENT BULBS ON A CVN

Direct Labor Hours				
bulbs /yr	23888			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	11944	17916	33920.96	95552
Full-Time maintainer	6.5692	9.8538	18.656528	52.5536
DL Maintenance Cost	$ 350,436.96	$ 525,655.44	$ 995,240.97	$ 2,803,495.68
Full-Time person w/2 performing task	13.1384	19.7076	37.313056	105.1072
DL Maintenance Cost w/2 performing task	$ 700,873.92	$ 1,051,310.88	$ 1,990,481.93	$ 5,606,991.36

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	281.7558974	0.2	56.35117949	$ 1,653.34
Receive/Store Used Bulbs	281.7558974	0.2	56.35117949	$ 1,653.34
Disposal off ship	5	2	10	$ 293.40
Disposal price	23888			$ 2,388.80
Requisitioned	61.25128205	0.2	12.25025641	$ 359.42
Receive New Bulbs	42.87589744	1	42.87589744	$ 1,257.98
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	197.8285128	
Full-Time Supply Person			0.108805682	
Total Supply Indirect Cost				$ 8,193.09

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
RA (0-4)	$ 175,523.00	321	$ 96.54
RO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	11944	17916	33920.96	95552
Full-Time maintenance/supply person required per year		13.247	19.816	37.422	105.216
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	13.247	19.816	37.422	105.216
LPO (E-6)	0.75	9.935	14.862	28.066	78.912
LCPO (E-7)	0.5	6.624	9.908	18.711	52.608
Dept LCPO (E-8)	0.068	0.901	1.348	2.545	7.155
CMC (E-9)	0.0125	0.166	0.248	0.468	1.315
DIVO O-1 (ELECTRO)	0.445	5.895	8.818	16.653	46.821
DIVO O-2 (AUXO)	0.445	5.895	8.818	16.653	46.821
Department Head (0-3)	0.045	0.596	0.892	1.684	4.735
RA (0-4)	0.0125	0.166	0.248	0.468	1.315
RO (0-5)	0.0125	0.166	0.248	0.468	1.315
Total Hrs Spent Supervising	3.2905	43.590	65.206	123.137	346.213
Full-Time Supervisors		0.024	0.036	0.068	0.190
OVHD /yr for Light bulbs		$ 31,048.10	$ 46,444.65	$ 87,707.39	$ 246,599.73

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		13.1384	19.7076	37.313056	105.1072
3M PQS 301	40	525.54	788.30	1492.52	4204.29
Maintenance Man 3M PQS	40	525.54	788.30	1492.52	4204.29
DCPO PQS	40	525.54	788.30	1492.52	4204.29
Electrical Training Annual	1	13.14	19.71	37.31	105.11
HAZMAT	1	13.14	19.71	37.31	105.11
JLG (jack lift) / Harness	1	13.14	19.71	37.31	105.11
Total HRS spent training maintenance man		1616.02	2424.03	4589.51	12928.19
Full-Time Maintenance Person to be trained		0.8888128	1.3332191	2.5242282	7.1105021
3M PQS 302-307 (if supervisor completes concurrently)	50	1.20	1.79	3.39	9.52
16 Supervisors (2	100	2.397446166	3.586323559	6.772514973	19.04172967
Full-Time Supervisors Trained		0.001319	0.001972478	0.003724883	0.010472951
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	198.4992923	297.7477308	563.7335461	1587.977432
Full-Time Trainers		0.109174611	0.163761252	0.31005345	0.873387588
Cost for Maintenance Man Training		$ 47,414.12	$ 71,121.18	$ 134,656.10	$ 379,312.97
Cost for Supervisors Training & Trainers		$ 143,094.12	$ 214,633.30	$ 406,358.32	$ 1,144,642.71
Cost for Training		$ 190,508.24	$ 285,754.48	$ 541,014.42	$ 1,523,955.67

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change T12 Fluorescent Light Bulbs on a CVN				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	11944	17916	33920.96	95552
Total DL Cost	$ 700,873.92	$ 1,051,310.88	$ 1,990,481.93	$ 5,606,991.36
Total Indirect Cost	$ 183,000.31	$ 269,936.04	$ 502,923.79	$ 1,400,100.53
Total Cost for Materials	$ 25,799.04	$ 25,799.04	$ 25,799.04	$ 25,799.04
Total Cost to change CFL bulbs	$ 909,673.27	$ 1,347,045.96	$ 2,519,204.77	$ 7,032,890.93
Actual Cost per light bulb	$ 38.08	$ 56.39	$ 105.46	$ 294.41

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	11944	17916	33920.96	95552
Maintenance	13.1384	19.7076	37.313056	105.1072
Supply	0.108805682	0.108805682	0.108805682	0.108805682
Full-Time trained	0.9993060	1.4989529	2.8380066	7.9943626
Full-Time Person Supervising	0.024	0.036	0.068	0.190
Total Full-Time people	14.27048611	21.35122179	40.3275934	113.4007856

C. FTE TO CHANGE 2,203 T12 FLUORESCENT BULBS ON A CG

Direct Labor Hours				
bulbs /yr	2203			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	**0.5**	0.75	1.42	4
hrs /yr to replacing bulbs	1101.5	1652.25	3128.26	8812
Full-Time maintainer	0.605825	0.9087375	1.720543	4.8466
DL Maintenance Cost	$ 32,318.01	$ 48,477.02	$ 91,783.15	$ 258,544.08
Full-Time person w/2 performing task	1.21165	1.817475	3.441086	9.6932
DL Maintenance Cost w/2 performing task	$ 64,636.02	$ 96,954.03	$ 183,566.30	$ 517,088.16

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	25.98410256	0.2	5.196820513	$ 152.47
Receive / Store Used Bulbs	25.98410256	0.2	5.196820513	$ 152.47
Disposal off ship	5	2	10	$ 293.40
Disposal price	2203			$ 220.30
Requisitioned	5.648717949	0.2	1.12974359	$ 33.15
Receive New Bulbs	3.954102564	1	3.954102564	$ 116.01
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	45.47748718	
Full-Time Supply Person			0.025012618	
Total Supply Indirect Cost				$ 1,554.61

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	1101.5	1652.25	3128.26	8812
Full-Time maintenance/supply person required per year		1.237	1.842	3.466	9.718
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	1.237	1.842	3.466	9.718
LPO (E-6)	0.75	0.927	1.382	2.600	7.289
LCPO (E-7)	0.5	0.618	0.921	1.733	4.859
Dept LCPO (E-8)	0.068	0.084	0.125	0.236	0.661
CMC (E-9)	0.0125	0.015	0.023	0.043	0.121
DIVO O-1 (ELECTRO)	0.445	0.550	0.820	1.542	4.325
DIVO O-2 (AUXO)	0.445	0.550	0.820	1.542	4.325
Department Head (0-3)	0.045	0.056	0.083	0.156	0.437
XO (0-4)	0.0125	0.015	0.023	0.043	0.121
CO (0-5)	0.0125	0.015	0.023	0.043	0.121
Total Hrs Spent Supervising	3.2905	4.069	6.063	11.405	31.978
Full-Time Supervisors		0.0022	0.003	0.006	0.018
OVHD /yr for Light bulbs		$ 2,898.42	$ 4,318.33	$ 8,123.66	$ 22,777.03

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		1.21165	1.817475	3.441086	9.6932
3M PQS 301	40	48.47	72.70	137.64	387.73
Maintenance Man 3M PQS	40	48.47	72.70	137.64	387.73
DCPO PQS	40	48.47	72.70	137.64	387.73
Electrical Training Annual	1	1.21	1.82	3.44	9.69
HAZMAT	1	1.21	1.82	3.44	9.69
JLG (jack lift) / Harness	1	1.21	1.82	3.44	9.69
Total HRS spent training maintenance man		149.03	223.55	423.25	1192.26
Full-Time Maintenance Person to be trained		0.0819681	0.1229522	0.2327895	0.6557450
3M PQS 302-307 (if supervisor completes concurrently)	50	0.11	0.17	0.31	0.88
16 Supervisors (2	100	0.223808109	0.333448803	0.627285863	1.758777824
Full-Time Supervisors Trained		0.000123	0.000183397	0.000345007	0.000967328
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	18.30634138	27.45923447	51.98898795	146.4468446
Full-Time Trainers		0.010068488	0.015102579	0.028593943	0.080545765
Cost for Maintenance Man Training		$ 4,372.63	$ 6,558.94	$ 12,418.26	$ 34,981.01
Cost for Supervisors Training & Trainers		$ 13,198.60	$ 19,796.09	$ 37,477.36	$ 105,563.45
Cost for Training		$ 17,571.23	$ 26,355.03	$ 49,895.62	$ 140,544.46

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	1101.5	1652.25	3128.26	8812
Total DL Cost	$ 64,636.02	$ 96,954.03	$ 183,566.30	$ 517,088.16
Total Indirect Cost	$ 22,689.26	$ 26,334.02	$ 47,820.63	$ 130,560.09
Total Cost for Materials	$ 2,379.24	$ 2,379.24	$ 2,379.24	$ 2,379.24
Total Cost to change CFL bulbs	$ 89,704.52	$ 125,667.29	$ 233,766.16	$ 650,027.49
Actual Cost per light bulb	$ 40.72	$ 57.04	$ 106.11	$ 295.06

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	1101.5	1652.25	3128.26	8812
Maintenance	1.21165	1.817475	3.441086	9.6932
Supply	0.025012618	0.025012618	0.025012618	0.025012618
Full-Time trained	0.0921597	0.1382382	0.2617284	0.7372581
Full-Time Person Supervising	0.002	0.003	0.006	0.018
Total Full-Time people	1.331060404	1.984060266	3.734099895	10.47305847

D. FULL-TIME PERSON TO 502 T12 FLUORESCENT BULBS ON A LCS

The LCS manning composition compares differently from the DDG and CVN. The LCS is manned differently as everyone on the ship is relied upon to complete every maintenance task necessary. While inport most remedial tasks and certain maintenance tasks are performed by contracted personnel. However for this analysis, we assume that ships company personnel complete this simple maintenance of changing light bulbs, as they would underway steaming. The manning on the ship is limited to 38 senior personnel, E-5 and above. There are 2 E-4 assigned to the ship, however, for simplicity, we grouped them in with the E-5 rank.

The average hourly pay rate for a maintenance person was calculated using every ships company individual on the ship. The average pay for the LCS crew was determined by the sum of the annual composite rate * the number of personnel in that rate, divide by the total number of personnel. To compute the hourly rate, .00055 was multiplied to the annual average. Multiplying the total annual rate by .00055 provided the estimated overhead cost for supervisor's hourly rate.

The number of lamps calculated is based on the number of fixtures instead of bulbs. This attempt assumes a person will change all bulbs per fixture at a time. There is an estimated total 904 bulbs on LCS Freedom class (Cizek, 2009). To figure the amount of tasks a supply person would complete, we used Appendix B. Divide the total number of each task: issuance, requisition or receiving new orders by the total number of bulbs (46/3900). We assumed the disposal, spill kits, and training to be constant between ship classes.

On an LCS the time spent supervising costs are comparable to the overhead cost on a DDG. Although the number of supervisors may spend less time with less individuals, the high cost still needs to be calculated and distributed appropriately.

After adding all the FTE sailors required to support only T12 light bulbs, a .5 FTE is required if using an average of .5 hrs to change a bulb. Using the USS George Washington's study average of 1.42 hrs, 1.5 FTE sailors will be required to change these bulbs. At the extreme estimated time of 4 hrs to change a bulb, 4.27 FTE sailors will be

engaged in changing only T12 light bulbs. For a crew that is manned to capacity, sailor's time must be managed more efficiently than changing out light bulbs.

Supervisors (Indirect OVHD for Officers/Enlisted)				
Military Pay Grade	Annual DoD Composite Rate FY 2015	AVG Hourly Rate	# of personnel on LCS	Total Annual Salaries (# in rank * Pay Rate)
E-5	82,120	45.17	14	1,149,680.00
E-6	96,939	53.32	10	969,390.00
E-7	110,765	60.92	6	664,590.00
E-8	122,917	67.60	2	245,834.00
0-2	118,890	65.39	3	356,670.00
0-3	150,534	82.79	3	451,602.00
0-4	175,523	96.54	1	175,523.00
0-5	197,347	108.54	1	197,347.00
Total			40	4,210,636.00
Average Pay for LCS crew				$ 105,265.90
Average Hourly Pay Rate				$ 57.90
Estimated OVHD cost for Supervising				$ 2,315.85

Direct Labor Hours				
bulbs /yr	502			
Avg Wage	$ 57.90			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	251	376.5	712.84	2008
Full-Time maintainer	0.13805	0.207075	0.392062	1.1044
DL Maintenance Cost	$ 14,531.96	$ 21,797.94	$ 41,270.76	$ 116,255.66
Full-Time person w/2 performing	0.2761	0.41415	0.784124	2.2088
DL Maintenance Cost w/2 performing task	$ 29,063.91	$ 43,595.87	$ 82,541.52	$ 232,511.32

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	10.6625641	0.2	2.132512821	$ 123.46
Receive / Store Used Bulbs	10.6625641	0.2	2.132512821	$ 123.46
Disposal off ship	5	2	10	$ 578.96
Disposal price	904			$ 90.40
Requisitioned	2.317948718	0.2	0.463589744	$ 26.84
Receive New Bulbs	1.622564103	1	1.622564103	$ 93.94
Training for HAZMAT	36	0.5	18	$ 1,042.13
Spill Kits	2	0.5	1	$ 57.90
Annual Inventory (bulbs)	1	1	1	$ 57.90
Total Hrs to perfrom Task		5.6	36.35117949	
Full-Time Supply Person			0.019993149	
Total Supply Indirect Cost				$ 2,195.00

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	452	678	1283.68	3616
Full-Time maintenance/supply person required per year		0.517	0.766	1.432	3.998
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	0.517	0.766	1.432	3.998
LPO (E-6)	0.5	0.259	0.383	0.716	1.999
LCPO (E-7)	0.0005	0.000	0.000	0.001	0.002
SEL (E-8)	0.04	0.021	0.031	0.057	0.160
DIVO O-2	0.13	0.067	0.100	0.186	0.520
Department Head (0-3)	0.12	0.062	0.092	0.172	0.480
XO (0-4)	0.04	0.021	0.031	0.057	0.160
CO (0-5)	0.04	0.021	0.031	0.057	0.160
Total Hrs Spent Supervising	1.8705	0.967	1.432	2.679	7.477
Full-Time Supervisors		5.32E-04	7.88E-04	1.47E-03	4.11E-03
OVHD /yr for Light bulbs		$ 2,240.38	$ 3,317.26	$ 6,203.31	$ 17,316.76

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		0.4972	0.7458	1.412048	3.9776
3M PQS 301	40	19.89	29.83	56.48	159.10
Maintenance Man 3M PQS	40	19.89	29.83	56.48	159.10
DCPO PQS	40	19.89	29.83	56.48	159.10
Electrical Training Annual	1	0.50	0.75	1.41	3.98
HAZMAT	1	0.50	0.75	1.41	3.98
JLG (jack lift) / Harness	1	0.50	0.75	1.41	3.98
Total HRS spent training maintenance man		61.16	91.73	173.68	489.24
Full-Time Maintenance Person to be trained		0.0336356	0.0504534	0.0955250	0.2690846
3M PQS 302-307 (if supervisor completes concurrently)	50	0.03	0.04	0.07	0.21
16 Supervisors (2 Divission+CMC/XO/CO)	100	0.053207538	0.078782885	0.147324813	0.411262389
Full-Time Supervisors Trained		0.000029	4.33306E-05	8.10286E-05	0.000226194
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	7.507260245	11.26076423	21.32015491	60.05631605
Full-Time Trainers		0.004128993	0.00619342	0.011726085	0.033030974
Cost for Maintenance Man Training		$ 3,540.68	$ 5,311.02	$ 10,055.53	$ 28,325.44
Cost for Supervisors Training & Trainers		$ 17,508.91	$ 26,260.69	$ 49,715.46	$ 140,033.83
Cost for Training		$ 21,049.59	$ 31,571.71	$ 59,770.99	$ 168,359.27

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change 502Fluorescent Light Bulbs on a LCS				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	452	678	1283.68	3616
Total DL Cost	$ 52,338.21	$ 78,507.31	$ 148,640.50	$ 418,705.64
Total Indirect Cost	$ 22,609.28	$ 32,437.95	$ 58,778.77	$ 160,210.59
Total Cost for Materials	$ 976.32	$ 976.32	$ 976.32	$ 976.32
Total Cost to change 1573 CFL bulbs	$ 75,923.81	$ 111,921.57	$ 208,395.59	$ 579,892.55
Actual Cost per light bulb	$ 83.99	$ 123.81	$ 230.53	$ 641.47

FULL-Time Person / Yr Required to Change 502 T12 Fluorescent Light Bulbs				
DL Hours	452	678	1283.68	3616
Maintenance	0.4972	0.7458	1.412048	3.9776
Supply	0.019993149	0.019993149	0.019993149	0.019993149
Full-Time trained	0.0336648	0.0504967	0.0956061	0.2693108
Full-Time Person Supervising	0.000532075	0.000787829	0.001473248	0.004112624
Total Full-Time people	0.551390068	0.817077678	1.529120473	4.271016607

E. FTE TO CHANGE 960 T12 BULBS ON A FFG

Direct Labor Hours				
bulbs /yr	960			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	480	720	1363.2	3840
Full-Time Equivlant	0.264	0.396	0.74976	2.112
DL Maintenance Cost	$ 14,083.20	$ 21,124.80	$ 39,996.29	$ 112,665.60
Full-Time Equivalent w/2 performing task	0.528	0.792	1.49952	4.224
DL Maintenance Cost w/2 performing task	$ 28,166.40	$ 42,249.60	$ 79,992.58	$ 225,331.20

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	11.32307692	0.2	2.264615385	$ 66.44
Receive / Store Used Bulbs	11.32307692	0.2	2.264615385	$ 66.44
Disposal off ship	5	2	10	$ 293.40
Disposal price	960			$ 96.00
Requisitioned	2.461538462	0.2	0.492307692	$ 14.44
Receive New Bulbs	1.723076923	1	1.723076923	$ 50.56
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	36.74461538	
Full-Time Supply Person			0.020209538	
Total Supply Indirect Cost				$ 1,174.09

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	480	720	1363.2	3840
Full-Time maintenance/supply person required per year		0.548	0.812	1.520	4.244
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	0.548	0.812	1.520	4.244
LPO (E-6)	0.75	0.411	0.609	1.140	3.183
LCPO (E-7)	0.5	0.274	0.406	0.760	2.122
Dept LCPO (E-8)	0.068	0.037	0.055	0.103	0.289
CMC (E-9)	0.0125	0.007	0.010	0.019	0.053
DIVO O-1 (ELECTRO)	0.445	0.244	0.361	0.676	1.889
DIVO O-2 (AUXO)	0.445	0.244	0.361	0.676	1.889
Department Head (0-3)	0.045	0.025	0.037	0.068	0.191
XO (0-4)	0.0125	0.007	0.010	0.019	0.053
CO (0-5)	0.0125	0.007	0.010	0.019	0.053
Total Hrs Spent Supervising	3.2905	1.804	2.673	5.001	13.966
Full-Time Supervisors		0.0010	0.001	0.003	0.008
OVHD /yr for Light bulbs		$ 1,284.86	$ 1,903.61	$ 3,561.86	$ 9,947.35

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		0.528	0.792	1.49952	4.224
3M PQS 301	40	21.12	31.68	59.98	168.96
Maintenance Man 3M PQS	40	21.12	31.68	59.98	168.96
DCPO PQS	40	21.12	31.68	59.98	168.96
Electrical Training Annual	1	0.53	0.79	1.50	4.22
HAZMAT	1	0.53	0.79	1.50	4.22
JLG (jack lift) / Harness	1	0.53	0.79	1.50	4.22
Total HRS spent training maintenance man		64.94	97.42	184.44	519.55
Full-Time Maintenance Person to be trained		0.0357192	0.0535788	0.1014425	0.2857536
3M PQS 302-307 (if supervisor completes concurrently)	50	0.05	0.07	0.14	0.38
16 Supervisors (2 Divission+CMC/XO/CO)	100	0.099213592	0.146991652	0.275036853	0.768106432
Full-Time Supervisors Trained		0.000055	8.08454E-05	0.00015127	0.000422459
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	7.977550147	11.96610093	22.65541701	63.81726105
Full-Time Trainers		0.004387653	0.006581356	0.012460479	0.035099494
Cost for Maintenance Man Training		$ 1,905.46	$ 2,858.19	$ 5,411.50	$ 15,243.66
Cost for Supervisors Training & Trainers		$ 5,752.89	$ 8,627.88	$ 16,332.83	$ 46,002.67
Cost for Training		$ 7,658.35	$ 11,486.06	$ 21,744.33	$ 61,246.32

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	480	720	1363.2	3840
Total DL Cost	$ 28,166.40	$ 42,249.60	$ 79,992.58	$ 225,331.20
Total Indirect Cost	$ 10,782.30	$ 12,370.58	$ 21,733.78	$ 57,789.11
Total Cost for Materials	$ 1,036.80	$ 1,036.80	$ 1,036.80	$ 1,036.80
Total Cost to change 1573 CFL bulbs	$ 39,985.50	$ 55,656.98	$ 102,763.16	$ 284,157.11
Actual Cost per light bulb	$ 41.65	$ 57.98	$ 107.04	$ 296.00

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	480	720	1363.2	3840
Maintenance	0.528	0.792	1.49952	4.224
Supply	0.020209538	0.020209538	0.020209538	0.020209538
Full-Time trained	0.0401614	0.0602410	0.1140543	0.3212756
Full-Time Person Supervising	0.001	0.001	0.003	0.008
Total Full-Time people	0.589363094	0.873920456	1.636534185	4.573166155

F. FTE TO CHANGE 17,327 BULBS ON LHA/D

Direct Labor Hours				
bulbs /yr	17327			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	8663.5	12995.25	24604.34	69308
Full-TimeEquivalent	4.764925	7.1473875	13.532387	38.1194
DL Maintenance Cost	$ 254,187.09	$ 381,280.64	$ 721,891.34	$ 2,033,496.72
Full-Time Equivalent w/2 performing task	9.52985	14.294775	27.064774	76.2388
DL Maintenance Cost w/2 performing task	$ 508,374.18	$ 762,561.27	$ 1,443,782.67	$ 4,066,993.44

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	204.3697436	0.2	40.87394872	$ 1,199.24
Receive / Store Used Bulbs	204.3697436	0.2	40.87394872	$ 1,199.24
Disposal off ship	5	2	10	$ 293.40
Disposal price	17327			$ 1,732.70
Requisitioned	44.42820513	0.2	8.885641026	$ 260.70
Receive New Bulbs	31.09974359	1	31.09974359	$ 912.47
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	151.7332821	
Full-Time Supply Person			0.083453305	
Total Supply Indirect Cost				$ 6,184.55

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	8663.5	12995.25	24604.34	69308
Full-Time maintenance/supply person required per year		9.613	14.378	27.148	76.322
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	9.613	14.378	27.148	76.322
LPO (E-6)	0.75	7.210	10.784	20.361	57.242
LCPO (E-7)	0.5	4.807	7.189	13.574	38.161
Dept LCPO (E-8)	0.068	0.654	0.978	1.846	5.190
CMC (E-9)	0.0125	0.120	0.180	0.339	0.954
DIVO 0-1 (ELECTRO)	0.445	4.278	6.398	12.081	33.963
DIVO 0-2 (AUXO)	0.445	4.278	6.398	12.081	33.963
Department Head (0-3)	0.045	0.433	0.647	1.222	3.435
XO (0-4)	0.0125	0.120	0.180	0.339	0.954
CO (0-5)	0.0125	0.120	0.180	0.339	0.954
Total Hrs Spent Supervising	3.2905	31.633	47.312	89.331	251.138
Full-Time Supervisors		0.0174	0.026	0.049	0.138
OVHD /yr for Light bulbs		$ 22,531.15	$ 33,698.93	$ 63,628.58	$ 178,880.08

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		9.52985	14.294775	27.064774	76.2388
3M PQS 301	40	381.19	571.79	1082.59	3049.55
Maintenance Man 3M PQS	40	381.19	571.79	1082.59	3049.55
DCPO PQS	40	381.19	571.79	1082.59	3049.55
Electrical Training Annual	1	9.53	14.29	27.06	76.24
HAZMAT	1	9.53	14.29	27.06	76.24
JLG (jack lift) / Harness	1	9.53	14.29	27.06	76.24
Total HRS spent training maintenance man		1172.17	1758.26	3328.97	9377.37
Full-Time Maintenance Person to be trained		0.6446944	0.9670415	1.8309320	5.1575548
3M PQS 302-307 (if supervisor completes concurrently)	50	0.87	1.30	2.46	6.91
16 Supervisors (2	100	1.739791599	2.602135813	4.913218307	13.8126106
Full-Time Supervisors Trained		0.000957	0.001431175	0.00270227	0.007596936
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	143.980226	215.9694129	408.9004336	1151.828842
Full-Time Trainers		0.079189124	0.118783177	0.224895238	0.633505863
Cost for Maintenance Man Training		$ 34,391.51	$ 51,587.27	$ 97,671.90	$ 275,132.11
Cost for Supervisors Training & Trainers		$ 103,793.01	$ 155,683.48	$ 294,749.93	$ 830,259.54
Cost for Training		$ 138,184.52	$ 207,270.75	$ 392,421.82	$ 1,105,391.64

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs

	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	8663.5	12995.25	24604.34	69308
Total DL Cost	$ 508,374.18	$ 762,561.27	$ 1,443,782.67	$ 4,066,993.44
Total Indirect Cost	$ 167,565.23	$ 196,231.96	$ 365,228.06	$ 1,015,989.17
Total Cost for Materials	$ 18,713.16	$ 18,713.16	$ 18,713.16	$ 18,713.16
Total Cost to change CFL bulbs	$ 694,652.57	$ 977,506.39	$ 1,827,723.90	$ 5,101,695.77
Actual Cost per light bulb	$ 40.09	$ 56.42	$ 105.48	$ 294.44

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	8663.5	12995.25	24604.34	69308
Maintenance	9.52985	14.294775	27.064774	76.2388
Supply	0.083453305	0.083453305	0.083453305	0.083453305
Full-Time trained	0.7248404	1.0872559	2.0585295	5.7986576
Full-Time Person Supervising	0.017	0.026	0.049	0.138
Total Full-Time people	10.35554158	15.49150554	29.25588896	82.25903703

G. FULL-TIME EQUIVALENT TO CHANGE 8,237 T12 BULBS ON LPD

Direct Labor Hours				
bulbs /yr	8237			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	4118.5	6177.75	11696.54	32948
Full-Time Equivalent	2.265175	3.3977625	6.433097	18.1214
DL Maintenance Cost	$ 120,836.79	$ 181,255.19	$ 343,176.48	$ 966,694.32
Full-Time Equivalent w/2 performing task	4.53035	6.795525	12.866194	36.2428
DL Maintenance Cost w/2 performing task	$ 241,673.58	$ 362,510.37	$ 686,352.97	$ 1,933,388.64

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	97.15435897	0.2	19.43087179	$ 570.10
Receive / Store Used Bulbs	97.15435897	0.2	19.43087179	$ 570.10
Disposal off ship	5	2	10	$ 293.40
Disposal price	8237			$ 823.70
Requisitioned	21.12051282	0.2	4.224102564	$ 123.94
Receive New Bulbs	14.78435897	1	14.78435897	$ 433.77
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	87.87020513	
Full-Time Supply Person			0.048328613	
Total Supply Indirect Cost				$ 3,401.81

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	4118.5	6177.75	11696.54	32948
Full-Time maintenance/supply person required per year		4.579	6.844	12.915	36.291
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	4.579	6.844	12.915	36.291
LPO (E-6)	0.75	3.434	5.133	9.686	27.218
LCPO (E-7)	0.5	2.289	3.422	6.457	18.146
Dept LCPO (E-8)	0.068	0.311	0.465	0.878	2.468
CMC (E-9)	0.0125	0.057	0.086	0.161	0.454
DIVO O-1 (ELECTRO)	0.445	2.038	3.046	5.747	16.150
DIVO O-2 (AUXO)	0.445	2.038	3.046	5.747	16.150
Department Head (0-3)	0.045	0.206	0.308	0.581	1.633
XO (0-4)	0.0125	0.057	0.086	0.161	0.454
CO (0-5)	0.0125	0.057	0.086	0.161	0.454
Total Hrs Spent Supervising	3.2905	15.066	22.520	42.495	119.416
Full-Time Supervisors		0.0083	0.012	0.023	0.066
OVHD /yr for Light bulbs		$ 10,731.27	$ 16,040.26	$ 30,268.38	$ 85,057.23

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		4.53035	6.795525	12.866194	36.2428
3M PQS 301	40	181.21	271.82	514.65	1449.71
Maintenance Man 3M PQS	40	181.21	271.82	514.65	1449.71
DCPO PQS	40	181.21	271.82	514.65	1449.71
Electrical Training Annual	1	4.53	6.80	12.87	36.24
HAZMAT	1	4.53	6.80	12.87	36.24
JLG (jack lift) / Harness	1	4.53	6.80	12.87	36.24
Total HRS spent training maintenance man		557.23	835.85	1582.54	4457.86
Full-Time Maintenance Person to be trained		0.3064782	0.4597173	0.8703980	2.4518254
3M PQS 302-307 (if supervisor completes concurrently)	50	0.41	0.62	1.17	3.28
16 Supervisors (2	100	0.828637809	1.238583517	2.337238016	6.567877729
Full-Time Supervisors Trained		0.000456	0.000681221	0.001285481	0.003612333
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	68.44626601	102.6688626	194.3854216	547.5626189
Full-Time Trainers		0.037645446	0.056467874	0.106911982	0.30115944
Cost for Maintenance Man Training		$ 16,349.22	$ 24,523.83	$ 46,431.78	$ 130,793.74
Cost for Supervisors Training & Trainers		$ 49,342.92	$ 74,010.88	$ 140,121.02	$ 394,694.38
Cost for Training		$ 65,692.13	$ 98,534.71	$ 186,552.79	$ 525,488.12

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	4118.5	6177.75	11696.54	32948
Total DL Cost	$ 241,673.58	$ 362,510.37	$ 686,352.97	$ 1,933,388.64
Total Indirect Cost	$ 80,490.21	$ 94,117.95	$ 174,456.21	$ 483,818.43
Total Cost for Materials	$ 8,895.96	$ 8,895.96	$ 8,895.96	$ 8,895.96
Total Cost to change CFL bulbs	$ 331,059.75	$ 465,524.28	$ 869,705.13	$ 2,426,103.03
Actual Cost per light bulb	$ 40.19	$ 56.52	$ 105.59	$ 294.54

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	4118.5	6177.75	11696.54	32948
Maintenance	4.53035	6.795525	12.866194	36.2428
Supply	0.048328613	0.048328613	0.048328613	0.048328613
Full-Time trained	0.3445794	0.5168664	0.9785955	2.7565972
Full-Time Person Supervising	0.008	0.012	0.023	0.066
Total Full-Time people	4.931544366	7.37310581	13.91649048	39.11340458

H. FTE TO CHANGE 7,291 T12 BULBS ON A LSD

Direct Labor Hours				
bulbs /yr	7291			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	3645.5	5468.25	10353.22	29164
Full-Time maintainer	2.005025	3.0075375	5.694271	16.0402
DL Maintenance Cost	$ 106,958.97	$ 160,438.46	$ 303,763.47	$ 855,671.76
Full-Time person w/2 performing task	4.01005	6.015075	11.388542	32.0804
DL Maintenance Cost w/2 performing task	$ 213,917.94	$ 320,876.91	$ 607,526.95	$ 1,711,343.52

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	85.99641026	0.2	17.19928205	$ 504.63
Receive / Store Used Bulbs	85.99641026	0.2	17.19928205	$ 504.63
Disposal off ship	5	2	10	$ 293.40
Disposal price	7291			$ 729.10
Requisitioned	18.69487179	0.2	3.738974359	$ 109.70
Receive New Bulbs	13.08641026	1	13.08641026	$ 383.96
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	81.22394872	
Full-Time Supply Person			0.044673172	
Total Supply Indirect Cost				$ 3,112.21

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	3645.5	5468.25	10353.22	29164
Full-Time maintenance/supply person required per year		4.055	6.060	11.433	32.125
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	4.055	6.060	11.433	32.125
LPO (E-6)	0.75	3.041	4.545	8.575	24.094
LCPO (E-7)	0.5	2.027	3.030	5.717	16.063
Dept LCPO (E-8)	0.068	0.276	0.412	0.777	2.185
CMC (E-9)	0.0125	0.051	0.076	0.143	0.402
DIVO O-1 (ELECTRO)	0.445	1.804	2.697	5.088	14.296
DIVO O-2 (AUXO)	0.445	1.804	2.697	5.088	14.296
Department Head (0-3)	0.045	0.182	0.273	0.514	1.446
XO (0-4)	0.0125	0.051	0.076	0.143	0.402
CO (0-5)	0.0125	0.051	0.076	0.143	0.402
Total Hrs Spent Supervising	3.2905	13.342	19.940	37.621	105.708
Full-Time Supervisors		0.0073	0.011	0.021	0.058
OVHD /yr for Light bulbs		$ 9,503.25	$ 14,202.52	$ 26,796.57	$ 75,293.05

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		4.01005	6.015075	11.388542	32.0804
3M PQS 301	40	160.40	240.60	455.54	1283.22
Maintenance Man 3M PQS	40	160.40	240.60	455.54	1283.22
DCPO PQS	40	160.40	240.60	455.54	1283.22
Electrical Training Annual	1	4.01	6.02	11.39	32.08
HAZMAT	1	4.01	6.02	11.39	32.08
JLG (jack lift) / Harness	1	4.01	6.02	11.39	32.08
Total HRS spent training maintenance man		493.24	739.85	1400.79	3945.89
Full-Time Maintenance Person to be trained		0.2712799	0.4069198	0.7704349	2.1702391
3M PQS 302-307 (if supervisor completes concurrently)	50	0.37	0.55	1.03	2.91
16 Supervisors (2	100	0.733813663	1.096678075	2.069154699	5.81391543
Full-Time Supervisors Trained		0.000404	0.000603173	0.001138035	0.003197653
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	60.58541604	90.87762826	172.060757	484.6763871
Full-Time Trainers		0.033321979	0.049982696	0.094633416	0.266572013
Cost for Maintenance Man Training		$ 14,471.55	$ 21,707.32	$ 41,099.20	$ 115,772.39
Cost for Supervisors Training & Trainers		$ 43,676.27	$ 65,511.18	$ 124,028.72	$ 349,364.94
Cost for Training		$ 58,147.82	$ 87,218.50	$ 165,127.92	$ 465,137.33

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	3645.5	5468.25	10353.22	29164
Total DL Cost	$ 213,917.94	$ 320,876.91	$ 607,526.95	$ 1,711,343.52
Total Indirect Cost	$ 71,428.28	$ 83,490.91	$ 154,602.50	$ 428,435.20
Total Cost for Materials	$ 7,874.28	$ 7,874.28	$ 7,874.28	$ 7,874.28
Total Cost to change CFL bulbs	$ 293,220.50	$ 412,242.10	$ 770,003.73	$ 2,147,653.00
Actual Cost per light bulb	$ 40.22	$ 56.54	$ 105.61	$ 294.56

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	3645.5	5468.25	10353.22	29164
Maintenance	4.01005	6.015075	11.388542	32.0804
Supply	0.044673172	0.044673172	0.044673172	0.044673172
Full-Time trained	0.3050055	0.4575057	0.8662063	2.4400087
Full-Time Person Supervising	0.007	0.011	0.021	0.058
Total Full-Time people	4.367066767	6.528220645	12.32011304	34.62322105

I. FTE TO CHANGE 4,660 T12 BULBS ON A SSBN/GN

Direct Labor Hours				
bulbs /yr	4660			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	2330	3495	6617.2	18640
Full-Time Equivalent	1.2815	1.92225	3.63946	10.252
DL Maintenance Cost	$ 68,362.20	$ 102,543.30	$ 194,148.65	$ 546,897.60
Full-Time Equivalent w/2 performing task	2.563	3.8445	7.27892	20.504
DL Maintenance Cost w/2 performing task	$ 136,724.40	$ 205,086.60	$ 388,297.30	$ 1,093,795.20

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	54.96410256	0.2	10.99282051	$ 322.53
Receive / Store Used Bulbs	54.96410256	0.2	10.99282051	$ 322.53
Disposal off ship	5	2	10	$ 293.40
Disposal price	4660			$ 466.00
Requisitioned	11.94871795	0.2	2.38974359	$ 70.12
Receive New Bulbs	8.364102564	1	8.364102564	$ 245.40
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	62.73948718	
Full-Time Supply Person			0.034506718	
Total Supply Indirect Cost				$ 2,306.78

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	2330	3495	6617.2	18640
Full-Time maintenance/supply person required per year		2.598	3.879	7.313	20.539
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	2.598	3.879	7.313	20.539
LPO (E-6)	0.75	1.948	2.909	5.485	15.404
LCPO (E-7)	0.5	1.299	1.940	3.657	10.269
Dept LCPO (E-8)	0.068	0.177	0.264	0.497	1.397
CMC (E-9)	0.0125	0.032	0.048	0.091	0.257
DIVO O-1 (ELECTRO)	0.445	1.156	1.726	3.254	9.140
DIVO O-2 (AUXO)	0.445	1.156	1.726	3.254	9.140
Department Head (0-3)	0.045	0.117	0.175	0.329	0.924
XO (0-4)	0.0125	0.032	0.048	0.091	0.257
CO (0-5)	0.0125	0.032	0.048	0.091	0.257
Total Hrs Spent Supervising	3.2905	8.547	12.764	24.065	67.582
Full-Time Supervisors		0.0047	0.007	0.013	0.037
OVHD /yr for Light bulbs		$ 6,087.90	$ 9,091.41	$ 17,140.82	$ 48,137.07

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		2.563	3.8445	7.27892	20.504
3M PQS 301	40	102.52	153.78	291.16	820.16
Maintenance Man 3M PQS	40	102.52	153.78	291.16	820.16
DCPO PQS	40	102.52	153.78	291.16	820.16
Electrical Training Annual	1	2.56	3.84	7.28	20.50
HAZMAT	1	2.56	3.84	7.28	20.50
JLG (jack lift) / Harness	1	2.56	3.84	7.28	20.50
Total HRS spent training maintenance man		315.25	472.87	895.31	2521.99
Full-Time Maintenance Person to be trained		0.1733870	0.2600804	0.4924189	1.3870956
3M PQS 302-307 (if supervisor completes concurrently)	50	0.24	0.35	0.66	1.86
16 Supervisors (2	100	0.470090272	0.702012938	1.323565684	3.7170076
Full-Time Supervisors Trained		0.000259	0.000386107	0.000727961	0.002044354
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	38.72294642	58.08403666	109.9717585	309.7782098
Full-Time Trainers		0.021297621	0.03194622	0.060484467	0.170378015
Cost for Maintenance Man Training		$ 9,249.41	$ 13,874.11	$ 26,268.31	$ 73,995.25
Cost for Supervisors Training & Trainers		$ 27,916.30	$ 41,871.95	$ 79,273.09	$ 223,295.42
Cost for Training		$ 37,165.70	$ 55,746.06	$ 105,541.41	$ 297,290.66

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	2330	3495	6617.2	18640
Total DL Cost	$ 136,724.40	$ 205,086.60	$ 388,297.30	$ 1,093,795.20
Total Indirect Cost	$ 46,225.38	$ 53,935.14	$ 99,385.69	$ 274,404.26
Total Cost for Materials	$ 5,032.80	$ 5,032.80	$ 5,032.80	$ 5,032.80
Total Cost to change CFL bulbs	$ 187,982.58	$ 264,054.54	$ 492,715.79	$ 1,373,232.26
Actual Cost per light bulb	$ 40.34	$ 56.66	$ 105.73	$ 294.69

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	2330	3495	6617.2	18640
Maintenance	2.563	3.8445	7.27892	20.504
Supply	0.034506718	0.034506718	0.034506718	0.034506718
Full-Time trained	0.1949431	0.2924128	0.5536314	1.5595180
Full-Time Person Supervising	0.005	0.007	0.013	0.037
Total Full-Time people	2.797150741	4.1784396	7.880293741	22.13519476

J. FTE TO CHANGE 1,740 T12 BULBS ON A SSN (LOS ANGELES)

Direct Labor Hours				
bulbs /yr	1740			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	870	1305	2470.8	6960
Full-Time Equivalent	0.4785	0.71775	1.35894	3.828
DL Maintenance Cost	$ 25,525.80	$ 38,288.70	$ 72,493.27	$ 204,206.40
Full-Time Equivalent w/2 performing task	0.957	1.4355	2.71788	7.656
DL Maintenance Cost w/2 performing task	$ 51,051.60	$ 76,577.40	$ 144,986.54	$ 408,412.80

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	20.52307692	0.2	4.104615385	$ 120.43
Receive / Store Used Bulbs	20.52307692	0.2	4.104615385	$ 120.43
Disposal off ship	5	2	10	$ 293.40
Disposal price	1740			$ 174.00
Requisitioned	4.461538462	0.2	0.892307692	$ 26.18
Receive New Bulbs	3.123076923	1	3.123076923	$ 91.63
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	42.22461538	
Full-Time Supply Person			0.023223538	
Total Supply Indirect Cost				$ 1,412.87

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	870	1305	2470.8	6960
Full-Time maintenance/supply person required per year		0.980	1.459	2.741	7.679
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	0.980	1.459	2.741	7.679
LPO (E-6)	0.75	0.735	1.094	2.056	5.759
LCPO (E-7)	0.5	0.490	0.729	1.371	3.840
Dept LCPO (E-8)	0.068	0.067	0.099	0.186	0.522
CMC (E-9)	0.0125	0.012	0.018	0.034	0.096
DIVO O-1 (ELECTRO)	0.445	0.436	0.649	1.220	3.417
DIVO O-2 (AUXO)	0.445	0.436	0.649	1.220	3.417
Department Head (0-3)	0.045	0.044	0.066	0.123	0.346
XO (0-4)	0.0125	0.012	0.018	0.034	0.096
CO (0-5)	0.0125	0.012	0.018	0.034	0.096
Total Hrs Spent Supervising	3.2905	3.225	4.800	9.020	25.268
Full-Time Supervisors		0.0018	0.003	0.005	0.014
OVHD /yr for Light bulbs		$ 2,297.40	$ 3,418.88	$ 6,424.45	$ 17,998.16

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		0.957	1.4355	2.71788	7.656
3M PQS 301	40	38.28	57.42	108.72	306.24
Maintenance Man 3M PQS	40	38.28	57.42	108.72	306.24
DCPO PQS	40	38.28	57.42	108.72	306.24
Electrical Training Annual	1	0.96	1.44	2.72	7.66
HAZMAT	1	0.96	1.44	2.72	7.66
JLG (jack lift) / Harness	1	0.96	1.44	2.72	7.66
Total HRS spent training maintenance man		117.71	176.57	334.30	941.69
Full-Time Maintenance Person to be trained		0.0647411	0.0971116	0.1838646	0.5179284
3M PQS 302-307 (if supervisor completes concurrently)	50	0.09	0.13	0.25	0.69
16 Supervisors (2	100	0.177398405	0.263996139	0.496078066	1.389766678
Full-Time Supervisors Trained		0.000098	0.000145198	0.000272843	0.000764372
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	14.45901206	21.68826035	41.06264576	115.6684881
Full-Time Trainers		0.007952457	0.011928543	0.022584455	0.063617668
Cost for Maintenance Man Training		$ 3,453.64	$ 5,180.46	$ 9,808.34	$ 27,629.13
Cost for Supervisors Training & Trainers		$ 10,425.18	$ 15,636.09	$ 29,601.32	$ 83,377.90
Cost for Training		$ 13,878.82	$ 20,816.55	$ 39,409.66	$ 111,007.02

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	870	1305	2470.8	6960
Total DL Cost	$ 51,051.60	$ 76,577.40	$ 144,986.54	$ 408,412.80
Total Indirect Cost	$ 18,254.09	$ 21,132.84	$ 38,103.65	$ 103,453.93
Total Cost for Materials	$ 1,879.20	$ 1,879.20	$ 1,879.20	$ 1,879.20
Total Cost to change CFL bulbs	$ 71,184.89	$ 99,589.44	$ 184,969.39	$ 513,745.93
Actual Cost per light bulb	$ 40.91	$ 57.24	$ 106.30	$ 295.26

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	870	1305	2470.8	6960
Maintenance	0.957	1.4355	2.71788	7.656
Supply	0.023223538	0.023223538	0.023223538	0.023223538
Full-Time trained	0.0727911	0.1091853	0.2067219	0.5823104
Full-Time Person Supervising	0.002	0.003	0.005	0.014
Total Full-Time people	1.054788598	1.570548816	2.952786199	8.275431645

K. FTE TO CHANGE 2,310 BULBS ON SSN (SEAWOLF)

Direct Labor Hours				
bulbs /yr	2310			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	1155	1732.5	3280.2	9240
Full-Time Equivalent	0.63525	0.952875	1.80411	5.082
DL Maintenance Cost	$ 33,887.70	$ 50,831.55	$ 96,241.07	$ 271,101.60
Full-Time Equivalent w/2 performing task	1.2705	1.90575	3.60822	10.164
DL Maintenance Cost w/2 performing task	$ 67,775.40	$ 101,663.10	$ 192,482.14	$ 542,203.20

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	27.24615385	0.2	5.449230769	$ 159.88
Receive / Store Used Bulbs	27.24615385	0.2	5.449230769	$ 159.88
Disposal off ship	5	2	10	$ 293.40
Disposal price	2310			$ 231.00
Requisitioned	5.923076923	0.2	1.184615385	$ 34.76
Receive New Bulbs	4.146153846	1	4.146153846	$ 121.65
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	46.22923077	
Full-Time Supply Person			0.025426077	
Total Supply Indirect Cost				$ 1,587.37

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	1155	1732.5	3280.2	9240
Full-Time maintenance/supply person required per year		1.296	1.931	3.634	10.189
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	1.296	1.931	3.634	10.189
LPO (E-6)	0.75	0.972	1.448	2.725	7.642
LCPO (E-7)	0.5	0.648	0.966	1.817	5.095
Dept LCPO (E-8)	0.068	0.088	0.131	0.247	0.693
CMC (E-9)	0.0125	0.016	0.024	0.045	0.127
DIVO O-1 (ELECTRO)	0.445	0.577	0.859	1.617	4.534
DIVO O-2 (AUXO)	0.445	0.577	0.859	1.617	4.534
Department Head (0-3)	0.045	0.058	0.087	0.164	0.459
XO (0-4)	0.0125	0.016	0.024	0.045	0.127
CO (0-5)	0.0125	0.016	0.024	0.045	0.127
Total Hrs Spent Supervising	3.2905	4.264	6.355	11.957	33.528
Full-Time Supervisors		0.0023	0.003	0.007	0.018
OVHD /yr for Light bulbs		$ 3,037.32	$ 4,526.19	$ 8,516.35	$ 23,881.44

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		1.2705	1.90575	3.60822	10.164
3M PQS 301	40	50.82	76.23	144.33	406.56
Maintenance Man 3M PQS	40	50.82	76.23	144.33	406.56
DCPO PQS	40	50.82	76.23	144.33	406.56
Electrical Training Annual	1	1.27	1.91	3.61	10.16
HAZMAT	1	1.27	1.91	3.61	10.16
JLG (jack lift) / Harness	1	1.27	1.91	3.61	10.16
Total HRS spent training maintenance man		156.27	234.41	443.81	1250.17
Full-Time Maintenance Person to be trained		0.0859493	0.1289240	0.2440961	0.6875946
3M PQS 302-307 (if supervisor completes concurrently)	50	0.12	0.17	0.33	0.92
16 Supervisors (2	100	0.234533462	0.349499418	0.657608183	1.844056858
Full-Time Supervisors Trained		0.000129	0.000192225	0.000361685	0.001014231
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	19.195465	28.79291532	54.51408215	153.5597694
Full-Time Trainers		0.010557506	0.015836103	0.029982745	0.084457873
Cost for Maintenance Man Training		$ 4,585.01	$ 6,877.51	$ 13,021.42	$ 36,680.05
Cost for Supervisors Training & Trainers		$ 13,839.54	$ 20,757.47	$ 39,297.52	$ 110,690.56
Cost for Training		$ 18,424.55	$ 27,634.98	$ 52,318.94	$ 147,370.61

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	1155	1732.5	3280.2	9240
Total DL Cost	$ 67,775.40	$ 101,663.10	$ 192,482.14	$ 542,203.20
Total Indirect Cost	$ 23,714.23	$ 27,536.02	$ 50,066.24	$ 136,824.37
Total Cost for Materials	$ 2,494.80	$ 2,494.80	$ 2,494.80	$ 2,494.80
Total Cost to change CFL bulbs	$ 93,984.43	$ 131,693.92	$ 245,043.17	$ 681,522.37
Actual Cost per light bulb	$ 40.69	$ 57.01	$ 106.08	$ 295.03

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	1155	1732.5	3280.2	9240
Maintenance	1.2705	1.90575	3.60822	10.164
Supply	0.025426077	0.025426077	0.025426077	0.025426077
Full-Time trained	0.0966358	0.1449523	0.2744405	0.7730667
Full-Time Person Supervising	0.002	0.003	0.007	0.018
Total Full-Time people	1.394907236	2.079623387	3.914662671	10.98093335

L. FTE TO CHANGE 2,018 T12 BULBS ON A SSN (VIRGINIA)

Direct Labor Hours				
bulbs /yr	2018			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	1009	1513.5	2865.56	8072
Full-Time Equivalent	0.55495	0.832425	1.576058	4.4396
DL Maintenance Cost	$ 29,604.06	$ 44,406.09	$ 84,075.53	$ 236,832.48
Full-Time Equivalent w/2 performing task	1.1099	1.66485	3.152116	8.8792
DL Maintenance Cost w/2 performing task	$ 59,208.12	$ 88,812.18	$ 168,151.06	$ 473,664.96

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	23.80205128	0.2	4.760410256	$ 139.67
Receive / Store Used Bulbs	23.80205128	0.2	4.760410256	$ 139.67
Disposal off ship	5	2	10	$ 293.40
Disposal price	2018			$ 201.80
Requisitioned	5.174358974	0.2	1.034871795	$ 30.36
Receive New Bulbs	3.622051282	1	3.622051282	$ 106.27
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	44.17774359	
Full-Time Supply Person			0.024297759	
Total Supply Indirect Cost				$ 1,497.97

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
XO (0-4)	$ 175,523.00	321	$ 96.54
CO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	1009	1513.5	2865.56	8072
Full-Time maintenance/supply person required per year		1.134	1.689	3.176	8.903
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	1.134	1.689	3.176	8.903
LPO (E-6)	0.75	0.851	1.267	2.382	6.678
LCPO (E-7)	0.5	0.567	0.845	1.588	4.452
Dept LCPO (E-8)	0.068	0.077	0.115	0.216	0.605
CMC (E-9)	0.0125	0.014	0.021	0.040	0.111
DIVO O-1 (ELECTRO)	0.445	0.505	0.752	1.414	3.962
DIVO O-2 (AUXO)	0.445	0.505	0.752	1.414	3.962
Department Head (0-3)	0.045	0.051	0.076	0.143	0.401
XO (0-4)	0.0125	0.014	0.021	0.040	0.111
CO (0-5)	0.0125	0.014	0.021	0.040	0.111
Total Hrs Spent Supervising	3.2905	3.732	5.558	10.452	29.297
Full-Time Supervisors		0.0021	0.003	0.006	0.016
OVHD /yr for Light bulbs		$ 2,658.27	$ 3,958.94	$ 7,444.71	$ 20,867.55

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		1.1099	1.66485	3.152116	8.8792
3M PQS 301	40	44.40	66.59	126.08	355.17
Maintenance Man 3M PQS	40	44.40	66.59	126.08	355.17
DCPO PQS	40	44.40	66.59	126.08	355.17
Electrical Training Annual	1	1.11	1.66	3.15	8.88
HAZMAT	1	1.11	1.66	3.15	8.88
JLG (jack lift) / Harness	1	1.11	1.66	3.15	8.88
Total HRS spent training maintenance man		136.52	204.78	387.71	1092.14
Full-Time Maintenance Person to be trained		0.0750847	0.1126271	0.2132406	0.6006779
3M PQS 302-307 (if supervisor completes concurrently)	50	0.10	0.15	0.29	0.81
16 Supervisors (2	100	0.205264275	0.305697739	0.574859421	1.611332766
Full-Time Supervisors Trained		0.000113	0.000168134	0.000316173	0.000886233
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	16.76907157	25.15333769	47.62317088	134.1487972
Full-Time Trainers		0.009222989	0.013834336	0.026192744	0.073781838
Cost for Maintenance Man Training		$ 4,005.43	$ 6,008.14	$ 11,375.42	$ 32,043.43
Cost for Supervisors Training & Trainers		$ 12,090.43	$ 18,133.88	$ 34,330.35	$ 96,698.81
Cost for Training		$ 16,095.86	$ 24,142.03	$ 45,705.77	$ 128,742.25

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	1009	1513.5	2865.56	8072
Total DL Cost	$ 59,208.12	$ 88,812.18	$ 168,151.06	$ 473,664.96
Total Indirect Cost	$ 20,917.11	$ 24,255.79	$ 43,938.03	$ 119,729.34
Total Cost for Materials	$ 2,179.44	$ 2,179.44	$ 2,179.44	$ 2,179.44
Total Cost to change CFL bulbs	$ 82,304.67	$ 115,247.41	$ 214,268.53	$ 595,573.74
Actual Cost per light bulb	$ 40.79	$ 57.11	$ 106.18	$ 295.13

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	1009	1513.5	2865.56	8072
Maintenance	1.1099	1.66485	3.152116	8.8792
Supply	0.024297759	0.024297759	0.024297759	0.024297759
Full-Time trained	0.0844206	0.1266296	0.2397496	0.6753460
Full-Time Person Supervising	0.002	0.003	0.006	0.016
Total Full-Time people	1.220671021	1.818834308	3.421911917	9.594957038

M. FTE TO CHANGE 383 T12 BULBS ON A MCM

Direct Labor Hours				
bulbs /yr	383			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	191.5	287.25	543.86	1532
Full-Time Equivalent	0.105325	0.1579875	0.299123	0.8426
DL Maintenance Cost	$ 5,618.61	$ 8,427.92	$ 15,956.85	$ 44,948.88
Full-Time Equivalent w/2 performing task	0.21065	0.315975	0.598246	1.6852
DL Maintenance Cost w/2 performing task	$ 11,237.22	$ 16,855.83	$ 31,913.70	$ 89,897.76

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	4.517435897	0.2	0.903487179	$ 26.51
Receive / Store Used Bulbs	4.517435897	0.2	0.903487179	$ 26.51
Disposal off ship	5	2	10	$ 293.40
Disposal price	383			$ 38.30
Requisitioned	0.982051282	0.2	0.196410256	$ 5.76
Receive New Bulbs	0.687435897	1	0.687435897	$ 20.17
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	32.69082051	
Full-Time Supply Person			0.017979951	
Total Supply Indirect Cost				$ 997.45

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
XO (0-3)	$ 150,534.00	67	$ 82.79
CO (0-4)	$ 175,523.00	321	$ 96.54
Total Annaul Salary	$ 952,426.00	323	$ 523.83
Total hourly rate	$ 523.83		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	191.5	287.25	543.86	1532
Full-Time maintenance/supply person required per year		0.229	0.334	0.616	1.703
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	0.229	0.334	0.616	1.703
LPO (E-6)	0.75	0.171	0.250	0.462	1.277
LCPO (E-7)	0.5	0.114	0.167	0.308	0.852
Dept LCPO (E-8)	0.068	0.016	0.023	0.042	0.116
CMC (E-9)	0.0125	0.003	0.004	0.008	0.021
DIVO O-1 (ELECTRO)	0.445	0.102	0.149	0.274	0.758
DIVO O-2 (AUXO)	0.445	0.102	0.149	0.274	0.758
Department Head (0-3)	0.045	0.010	0.015	0.028	0.077
XO (0-4)	0.0125	0.003	0.004	0.008	0.021
CO (0-5)	0.0125	0.003	0.004	0.008	0.021
Total Hrs Spent Supervising	3.2905	0.752	1.099	2.028	5.604
Full-Time Supervisors		0.0004	0.001	0.001	0.003
OVHD /yr for Light bulbs		$ 394.08	$ 575.63	$ 1,062.17	$ 2,935.73

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		0.21065	0.315975	0.598246	1.6852
3M PQS 301	40	8.43	12.64	23.93	67.41
Maintenance Man 3M PQS	40	8.43	12.64	23.93	67.41
DCPO PQS	40	8.43	12.64	23.93	67.41
Electrical Training Annual	1	0.21	0.32	0.60	1.69
HAZMAT	1	0.21	0.32	0.60	1.69
JLG (jack lift) / Harness	1	0.21	0.32	0.60	1.69
Total HRS spent training maintenance man		25.91	38.86	73.58	207.28
Full-Time Maintenance Person to be trained		0.0142505	0.0213757	0.0404713	0.1140038
3M PQS 302-307 (if supervisor completes concurrently)	50	0.02	0.03	0.06	0.15
16 Supervisors (2	100	0.041376877	0.060438332	0.111523032	0.30823725
Full-Time Supervisors Trained		0.000023	3.32411E-05	6.13377E-05	0.00016953
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	3.182930241	4.774195813	9.038787544	25.46064824
Full-Time Trainers		0.001750612	0.002625808	0.004971333	0.014003357
Cost for Maintenance Man Training		$ 760.20	$ 1,140.30	$ 2,158.96	$ 6,081.58
Cost for Supervisors Training & Trainers		$ 1,689.00	$ 2,532.55	$ 4,793.25	$ 13,498.63
Cost for Training		$ 2,449.20	$ 3,672.84	$ 6,952.21	$ 19,580.21

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change 1428 Fluorescent Light Bulbs on a DDG				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	191.5	287.25	543.86	1532
Total DL Cost	$ 11,237.22	$ 16,855.83	$ 31,913.70	$ 89,897.76
Total Indirect Cost	$ 4,505.73	$ 4,770.63	$ 7,517.87	$ 18,096.81
Total Cost for Materials	$ 413.64	$ 413.64	$ 413.64	$ 413.64
Total Cost to change CFL bulbs	$ 16,156.59	$ 22,040.10	$ 39,845.21	$ 108,408.21
Actual Cost per light bulb	$ 42.18	$ 57.55	$ 104.03	$ 283.05

FULL-Time Person / Yr Required to Change 1428 T12 Fluorescent Light Bulbs				
DL Hours	191.5	287.25	543.86	1532
Maintenance	0.21065	0.315975	0.598246	1.6852
Supply	0.017979951	0.017979951	0.017979951	0.017979951
Full-Time trained	0.0160238	0.0240348	0.0455040	0.1281767
Full-Time Person Supervising	0.000	0.001	0.001	0.003
Total Full-Time people	0.245067561	0.358594092	0.662845194	1.834438991

N. FTE TO CHANGE 88 T12 BULBS ON A PC

Direct Labor Hours				
bulbs /yr	88			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	44	66	124.96	352
Full-Time Equivalent	0.0242	0.0363	0.068728	0.1936
DL Maintenance Cost	$ 1,290.96	$ 1,936.44	$ 3,666.33	$ 10,327.68
Full-Time Equivalent w/2 performing task	0.0484	0.0726	0.137456	0.3872
DL Maintenance Cost w/2 performing task	$ 2,581.92	$ 3,872.88	$ 7,332.65	$ 20,655.36

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	1.037948718	0.2	0.207589744	$ 6.09
Receive / Store Used Bulbs	1.037948718	0.2	0.207589744	$ 6.09
Disposal off ship	5	2	10	$ 293.40
Disposal price	88			$ 8.80
Requisitioned	0.225641026	0.2	0.045128205	$ 1.32
Receive New Bulbs	0.157948718	1	0.157948718	$ 4.63
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	30.61825641	
Full-Time Supply Person			0.016840041	
Total Supply Indirect Cost				$ 907.14

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
XO (0-3)	$ 150,534.00	67	$ 82.79
CO (0-4)	$ 175,523.00	321	$ 96.54
Total Annaul Salary	$ 952,426.00	323	$ 523.83
Total hourly rate	$ 523.83		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	44	66	124.96	352
Full-Time maintenance/supply person required per year		0.065	0.089	0.154	0.404
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	0.065	0.089	0.154	0.404
LPO (E-6)	0.75	0.049	0.067	0.116	0.303
LCPO (E-7)	0.5	0.033	0.045	0.077	0.202
Dept LCPO (E-8)	0.068	0.004	0.006	0.010	0.027
CMC (E-9)	0.0125	0.001	0.001	0.002	0.005
DIVO O-1 (ELECTRO)	0.445	0.029	0.040	0.069	0.180
DIVO O-2 (AUXO)	0.445	0.029	0.040	0.069	0.180
Department Head (0-3)	0.045	0.003	0.004	0.007	0.018
XO (0-4)	0.0125	0.001	0.001	0.002	0.005
CO (0-5)	0.0125	0.001	0.001	0.002	0.005
Total Hrs Spent Supervising	3.2905	0.215	0.294	0.508	1.329
Full-Time Supervisors		0.0001	0.000	0.000	0.001
OVHD /yr for Light bulbs		$ 112.45	$ 154.17	$ 265.96	$ 696.43

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		0.0484	0.0726	0.137456	0.3872
3M PQS 301	40	1.94	2.90	5.50	15.49
Maintenance Man 3M PQS	40	1.94	2.90	5.50	15.49
DCPO PQS	40	1.94	2.90	5.50	15.49
Electrical Training Annual	1	0.05	0.07	0.14	0.39
HAZMAT	1	0.05	0.07	0.14	0.39
JLG (jack lift) / Harness	1	0.05	0.07	0.14	0.39
Total HRS spent training maintenance man		5.95	8.93	16.91	47.63
Full-Time Maintenance Person to be trained		0.0032743	0.0049114	0.0092989	0.0261941
3M PQS 302-307 (if supervisor completes concurrently)	50	0.01	0.01	0.01	0.04
16 Supervisors (2	100	0.01180698	0.016186635	0.027924112	0.073122157
Full-Time Supervisors Trained		0.000006	8.90265E-06	1.53583E-05	4.02172E-05
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	0.731608106	1.097225261	2.077079236	5.850248272
Full-Time Trainers		0.000402384	0.000603474	0.001142394	0.003217637
Cost for Maintenance Man Training		$ 174.67	$ 262.00	$ 496.05	$ 1,397.34
Cost for Supervisors Training & Trainers		$ 389.43	$ 583.24	$ 1,102.67	$ 3,102.86
Cost for Training		$ 564.09	$ 845.24	$ 1,598.73	$ 4,500.20

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change Fluorescent Light Bulbs on a DDG				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	44	66	124.96	352
Total DL Cost	$ 2,581.92	$ 3,872.88	$ 7,332.65	$ 20,655.36
Total Indirect Cost	$ 2,248.69	$ 2,309.55	$ 2,940.77	$ 5,371.44
Total Cost for Materials	$ 95.04	$ 95.04	$ 95.04	$ 95.04
Total Cost to change CFL bulbs	$ 4,925.65	$ 6,277.47	$ 10,368.46	$ 26,121.84
Actual Cost per light bulb	$ 55.97	$ 71.33	$ 117.82	$ 296.84

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	44	66	124.96	352
Maintenance	0.0484	0.0726	0.137456	0.3872
Supply	0.016840041	0.016840041	0.016840041	0.016840041
Full-Time trained	0.0036831	0.0055238	0.0104567	0.0294519
Full-Time Person Supervising	0.000	0.000	0.000	0.001
Total Full-Time people	0.069041249	0.095125674	0.165031932	0.434223196

O. FTE TO CHANGE 8,193 T12 BULBS ON A LCC

Direct Labor Hours				
bulbs /yr	8193			
Avg Wage	$ 29.34			
hrs to replace a bulb per person	0.5	0.75	1.42	4
hrs /yr to replacing bulbs	4096.5	6144.75	11634.06	32772
Full-Time Equivalent	2.253075	3.3796125	6.398733	18.0246
DL Maintenance Cost	$ 120,191.31	$ 180,286.97	$ 341,343.32	$ 961,530.48
Full-Time Equivalent w/2 performing task	4.50615	6.759225	12.797466	36.0492
DL Maintenance Cost w/2 performing task	$ 240,382.62	$ 360,573.93	$ 682,686.64	$ 1,923,060.96

Supply personnel (Indirect OVHD for T12 only)				
	# of times Task was performed	Hrs / Task	HRS / year	Price / year
Issued	96.63538462	0.2	19.32707692	$ 567.06
Receive/Store Used Bulbs	96.63538462	0.2	19.32707692	$ 567.06
Disposal off ship	5	2	10	$ 293.40
Disposal price	8193			$ 819.30
Requisitioned	21.00769231	0.2	4.201538462	$ 123.27
Receive New Bulbs	14.70538462	1	14.70538462	$ 431.46
Training for HAZMAT	36	0.5	18	$ 528.12
Spill Kits	2	0.5	1	$ 29.34
Annual Inventory (bulbs)	1	1	1	$ 29.34
Total Hrs to perfrom Task		5.6	87.56107692	
Full-Time Supply Person			0.048158592	
Total Supply Indirect Cost				$ 3,388.34

Supervisors (Indirect OVHD for Officers/Enlisted)			
	Annual Salary	# of personnel Supervising	Estimated OVHD = Salary * .00055
WCS (E-5)	$ 82,120.00	6	$ 45.17
LPO (E-6)	$ 96,939.00	7	$ 53.32
LCPO (E-7)	$ 110,765.00	8	$ 60.92
Dept LCPO (E-8)	$ 122,917.00	60	$ 67.60
CMC (E-9)	$ 145,276.00	320	$ 79.90
DIVO O-1 (ELECTRO)	$ 94,738.00	9	$ 52.11
DIVO O-2 (AUXO)	$ 118,890.00	9	$ 65.39
Department Head (0-3)	$ 150,534.00	67	$ 82.79
RA (0-4)	$ 175,523.00	321	$ 96.54
RO (0-5)	$ 197,347.00	322	$ 108.54
Total Annaul Salary	$ 1,295,049.00	323	$ 712.28
Total hourly rate	$ 712.28		

Hrs Supervisoring DL (Indirect OVHD)					
	DL hrs	4096.5	6144.75	11634.06	32772
Full-Time maintenance/supply person required per year		4.554	6.807	12.846	36.097
	HRS Supervising a person / day	Hrs / yr to be supervised			
WCS (E-5)	1	4.554	6.807	12.846	36.097
LPO (E-6)	0.75	3.416	5.106	9.634	27.073
LCPO (E-7)	0.5	2.277	3.404	6.423	18.049
Dept LCPO (E-8)	0.068	0.310	0.463	0.874	2.455
CMC (E-9)	0.0125	0.057	0.085	0.161	0.451
DIVO O-1 (ELECTRO)	0.445	2.027	3.029	5.716	16.063
DIVO O-2 (AUXO)	0.445	2.027	3.029	5.716	16.063
Department Head (0-3)	0.045	0.205	0.306	0.578	1.624
RA (0-4)	0.0125	0.057	0.085	0.161	0.451
RO (0-5)	0.0125	0.057	0.085	0.161	0.451
Total Hrs Spent Supervising	3.2905	14.986	22.400	42.269	118.778
Full-Time Supervisors		0.008	0.012	0.023	0.065
OVHD /yr for Light bulbs		$ 10,674.15	$ 15,954.79	$ 30,106.90	$ 84,603.09

HRS Spent Training/Qualifying for Maintenance Man Per Year					
	Training HRS per year	.5 hrs/ bulb	0.75 hrs / bulb	1.45 hrs / bulb	4 hrs / bulb
Full-Time maintenance person required per year		4.50615	6.759225	12.797466	36.0492
3M PQS 301	40	180.25	270.37	511.90	1441.97
Maintenance Man 3M PQS	40	180.25	270.37	511.90	1441.97
DCPO PQS	40	180.25	270.37	511.90	1441.97
Electrical Training Annual	1	4.51	6.76	12.80	36.05
HAZMAT	1	4.51	6.76	12.80	36.05
JLG (jack lift) / Harness	1	4.51	6.76	12.80	36.05
Total HRS spent training maintenance man		554.26	831.38	1574.09	4434.05
Full-Time Maintenance Person to be trained		0.3048410	0.4572616	0.8657486	2.4387284
3M PQS 302-307 (if supervisor completes concurrently)	50	0.41	0.62	1.16	3.27
16 Supervisors (2	100	0.824227383	1.231983264	2.324769025	6.532809715
Full-Time Supervisors Trained		0.000453	0.000677591	0.001278623	0.003593045
Trainer (E-5) (Trains Supervisors & maintenance persons)	223	68.08064508	102.1204331	193.3470651	544.6376779
Full-Time Trainers		0.037444355	0.056166238	0.106340886	0.299550723
Cost for Maintenance Man Training		$ 16,261.88	$ 24,392.83	$ 46,183.75	$ 130,095.07
Cost for Supervisors Training & Trainers		$ 49,079.35	$ 73,615.54	$ 139,372.54	$ 392,586.03
Cost for Training		$ 65,341.24	$ 98,008.37	$ 185,556.29	$ 522,681.11

Tools (Indirect OVHD)	
	Price
JLG	400
Screw Driver set	25
6 ft Ladder	120
Electrical Gloves (1 pair)	55
Electricians mat	65
Total	665

Total Cost to change T12 Fluorescent Light Bulbs				
	.5 hrs / bulb	.75 hrs / bulb	1.42 hrs / bulb	4 hrs / bulb
DL Hours	4096.5	6144.75	11634.06	32772
Total DL Cost	$ 240,382.62	$ 360,573.93	$ 682,686.64	$ 1,923,060.96
Total Indirect Cost	$ 63,806.84	$ 93,623.67	$ 173,532.78	$ 481,242.46
Total Cost for Materials	$ 8,848.44	$ 8,848.44	$ 8,848.44	$ 8,848.44
Total Cost to change CFL bulbs	$ 313,037.90	$ 463,046.04	$ 865,067.86	$ 2,413,151.86
Actual Cost per light bulb	$ 38.21	$ 56.52	$ 105.59	$ 294.54

FULL-Time Person / Yr Required to Change T12 Fluorescent Light Bulbs				
DL Hours	4096.5	6144.75	11634.06	32772
Maintenance	4.50615	6.759225	12.797466	36.0492
Supply	0.048158592	0.048158592	0.048158592	0.048158592
Full-Time trained	0.3427387	0.5141054	0.9733681	2.7418721
Full-Time Person Supervising	0.008	0.012	0.023	0.065
Total Full-Time people	4.905289593	7.333808825	13.84224037	38.90455884

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California